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DIVERSITY OF SPORT ACTIVITIES, LEISURE-TIME PHYSICAL ACTIVITY, AND SPINAL PAIN: A FINNISH TWIN STUDY

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ACADEMIC DISSERTATION

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For all sport nerds

ABSTRACT

Diverse physical activity is globally recommended across all age groups but is sparsely studied. Previous literature has focused on the dose of physical activity that is required to achieve numerous health benefits, and links have been found between earlier and current physical activity, as well as physical activity and spinal pains. Simultaneously, evidence indicates that frequent participation in only a single sport increases the risk of overuse injuries, burnout, and even dropout from sports among young athletes. Frequent spinal pains are related to both low and high intensity of physical activity, as well as to specific risk sports among athletes. Similar population-based evidence is scarce. This thesis aimed to study the diversity of sport activities in adolescence and leisure-time physical activity in adulthood, as well as, associations between the diversity of sport activities and spinal pains, including low back pain and neck-shoulder region pain, in adulthood.

This thesis includes three studies based on the FinnTwin16 study of Finnish twins born in 1975–79. The first survey wave took place in 1991-1995 when twins were 16 years of age and 4 follow-ups have occurred since. The second and fifth survey waves, conducted when twins were 17 and 34 years of age on average, provided information on participation in different leisure-time sport activities. Additionally, the fifth wave included more items on leisure-time physical activity behavior and several items on spinal pains including non-specific low back pain and neck-shoulder region pain, as well as, radiatiang and non-radiating low back pain lasting more than one day. Categorized variables were created for the quantity and quality of sport activities, leisure-time physical activity level, and spinal pains. Aiming to study the participation in a diversity of sport activities in comparison to single sport, the studied sample included only individuals who engaged in leisure-time physical activity at least once month and reported at least one sport activity at the wave of interest. The chosen sample was large and representative with 3734 individuals (57% females). The studies included cross-sectional, longitudinal, and within-pair analyses.

Participation in five or more sport activities in adolescence was related to higher levels of leisure-time physical activity in adulthood, but only among females. Shared familial factors, however, seemed to confound the detected association. Neither participation in several sport activities in adolescence nor adulthood was associated with neck–shoulder region pain in adulthood. In contrast, participation in several sport activities in adulthood was related to less weekly low back pain among both sexes in cross-sectional but not in longitudinal design. Familial factors did not seem to confound the detected cross-sectional association. In further cross-sectional investigation, participation in endurance sports was related to less both radiating and non-radiating low back pain in adulthood.

Overall the findings provide moderate support for additional health benefits related to participation in a diversity of sport activities compared to single sport activity. Promoting participation in several sport activities during adolescence may help to better maintain leisure-time physical activity levels through the transition from adolescence to adulthood, especially among females. In adulthood, participation in several sport activities, especially in endurance sports, may be related to a lower prevalence of weekly low back pain. Future studies should confirm and further investigate the direction of the detected associations in longitudinal study designs including objective measurement of leisure-time physical activity and standardized measures of low back and neck–shoulder region pain. Furthermore, the contribution of the shared familial factors on the observed associations remains unexplored.

TIIVISTELMÄ

Monipuolista liikuntaa suositellaan kaiken ikäisille, mutta liikunnan monipuolisuutta on tutkittu vain vähän. Aiempi tutkimus on keskittynyt selvittämään terveyshyötyjen saavuttamiseksi vaadittavaa liikunnan määrää. Yhteys on löytynyt aiemman ja nykyisen liikunta-aktiivisuuden välille sekä liikunnan ja selkäkipujen välille. Nuorilla urheilijoilla toistuva, yksipuolinen harjoittelu on liitetty vammautumis- ja loppuunpalamisriskiin, jopa urheilun lopettamiseen. Toistuvat selkäkivut on puolestaan yhdistetty sekä vähäiseen että hyvin runsaaseen liikunta-aktiivisuuteen ja muutamiin riskilajeihin urheilijoiden keskuudessa. Vastaavaa tietoa väestötasolta on vähäisesti. Tämän väitöskirjatyön tavoitteena oli tutkia nuoruuden monipuolisen liikunnan yhteyttä aikuisiän vapaa-ajan liikunta-aktiivisuuteen sekä liikunnan monipuolisuuden yhteyttä alaselän ja niska-hartiaseudun kipuihin poikittais- ja pitkittäisasetelmissa.

Tämä väitöskirja koostuu kolmesta osatyöstä. Aineistona on Nuorten Kaksosten Terveystutkimus, johon kuuluvat suomalaiset vuosina 1975-79 syntyneet kaksoset. Ensimmäinen kysely toteutettiin vuosina 1991-95, kun kaksoset olivat 16-vuotiaita. Tämän jälkeen on toteutettu neljä seurantakyselyä. Toinen (1992-96) ja viides (2010-12) kysely keräsivät tietoa eri vapaa-ajan liikuntalajeihin osallistumisesta. Lisäksi viides kysely sisälsi kysymyksiä epäspesifistä alaselän ja niska-hartiaseudun kivusta sekä yli yhden päivän kestäneestä säteilevästä ja säteilemättömästä alaselän kivusta. Luokitellut muuttujat luotiin liikuntalajien määrälle ja tyypille, vapaa-ajan liikunta-aktiivisudelle ja selän alueen kivuille. Tavoitteena oli tutkia liikunnan monipuolisuutta verrattuna yhteen liikuntalajiin, joten tutkimusaineistossa mukana olivat vain ne, jotka osallistuivat vapaa-ajan liikuntaan vähintään kerran kuussa ja ilmoittivat vähintään yhden liikuntalajin. Valittuun otokseen kuului 3734 yksilöä (57% naisia), joten sitä voitiin pitää suurena ja edustavana. Osatöissä tehtiin poikittaisia, pitkittäisiä ja pareittaisia analyysejä.

Osallistuminen viiteen tai useampaan liikuntalajiin nuoruudessa oli yhteydessä korkeaan liikunta-aktiivisuuteen aikuisiällä, mutta vain naisilla. Jaetut perhe- ja perintötekijät saattavat vaikuttaa tähän yhteyteen. Osallistuminen moneen liikuntalajiin nuoruudessa tai aikuisiällä ei ollut yhteydessä niska-hartiaseudun kipuihin aikuisiällä. Sen sijaan osallistuminen viiteen tai useampaan liikuntalajiin oli yhteydessä vähäiseen viikoittaisten alaselkäkipujen esiintymiseen miehillä ja naisilla poikkileikkaus-, mutta ei pitkittäisasetelmassa. Perhe- ja perintötekijöiden ei todettu vaikuttavan poikkileikkausasetelmassa havaittuu yhteyteen. Tarkemmin alaselän kipuja analysoineessa poikkileikkaustutkimuksessa kestävyysliikuntalajit olivat yhteydessä vähäiseen säteilevään ja säteilemättömään alaselän kipuun.

Kaikkiaan löydökset antavat kohtalaista tukea sille, että lisää terveyshyötyjä voi saavuttaa liikunnan monipuolisuudella yhteen

liikuntalajiin verrattuna. Erityisesti tyttöjen kannustaminen useiden liikuntalajien pariin nuoruudessa voi auttaa heitä paremmin säilyttämään liikunta-aktiivisuutensa siirryttäessä nuoruudesta aikuisuuteen. Aikuisiällä osallistuminen useaan liikuntalajiin ja etenkin kestävyysliikuntalajeihin voi liittyä vähäiseen alaselän kipujen esiintymiseen. Tulevaisuudessa tässä väitöskirjassa löydettyjen yhteyksien suunta tulisi vahvistaa pitkittäistutkimuksissa, jotka hyödyntävät objektiivisesti mitattua liikunta-aktiivisuutta sekä standardoituja selän kipumittareita. Lisäksi tarvitaan lisätutkimuksia selvittämään yhteisten perhe- ja perintötekijöiden osuus löydettyjen yhteyksien taustalla.

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I **Mäkelä S**, Aaltonen S, Korhonen T, Rose RJ, Kaprio J. Diversity of leisure-time sport activities in adolescence as a predictor of leisure-time physical activity in adulthood. Scand J Med Sci Sports. 2017;27(12):1902–12. doi: 10.1111/sms.12837

II **Kaartinen S**, Aaltonen S, Korhonen T, Latvala A, Mikkelsson M, Kujala UM, Kaprio J. Is diversity of leisure-time sport activities associated with low back and neck–shoulder region pain? A Finnish twin cohort study. Prev Med Rep. 2019;15:100933. doi: 10.1016/j.pmedr.2019.100933.

III **Kaartinen S**, Aaltonen S, Korhonen T, Rottensteiner M, Kujala UM, Kaprio J. Associations between the diversity of sport activities and the type of low back pain. Eur J Spor Sci. 2020. doi: 10.1080/17461391.2019.1706642.

The publications are referred to in the text by their Roman numerals. The original publications have been reprinted with the permission of their copyright holders.

ABBREVIATIONS

BMI	body mass index
CI	confidence interval
DZ	dizygotic
GHQ-12	the 12-item General Health Questionnaire
HLAQ	Historical Leisure Activity Questionnraire
LBP	low back pain
LTMET	leisure-time metabolic equivalent of task
LTPA	leisure-time physical activity
MET	metabolic equivalent of task
MVPA	moderate to vigorous physical activity
MZ	monozygotic
NSP	neck-shoulder region pain
ODI	Oswestry Disability Index
OMPSQ	Örebro Musculoskeletal Pain Screening Questionnaire
OR	Odds Ratio
p	p-value
QTF	The Quebec Task Force
RMDQ	Roland-Morris Disability Questionnaire
SBST	STarT Back Screening Tool
SD	standard deviation
WHO	World Health Organization

CONTENTS

1 INTRODUCTION

Physical activity is an essential part of sustaining a healthy and independent life (Bull and Bauman 2011). Unfortunately, few individuals meet the evidence-based physical activity guidelines that suggest participating in not only moderate to vigorous intensity activities but also muscle-strengthening and balance-, agility-, and flexibility-improving activities (Bennie et al. 2017; Hallal et al. 2012; World Health Organization 2010). In general, the level of overall physical activity already starts to decline at the time of entering school and the decline finally levels out in adulthood (Lounassalo et al. 2019; Telama 2009). Notably, not all children experience a decline in their physical activity levels, since the training load may markedly increase in adolescence among young athletes. A growing body of evidence, however, indicates that intensive participation in a single sport increases the risk of overuse injuries, burnout, and even dropout from sports among young athletes (Fabricant et al. 2016; Myer et al. 2015). The goal of sport participation in childhood should be the promotion of lifelong physical activity, which is required to achieve the numerous health benefits (Brenner et al. 2007; Piercy et al. 2018). Some studies have related participation in several sport activities in adolescence to higher physical activity levels in adulthood (Cleland et al. 2012; Engström 2008; Kjonniksen et al. 2008).

Simultaneously with the decreasing physical activity levels, an increasing load of disability related to spinal pains is burdening individuals and societies worldwide (Hartvigsen et al. 2018; Hogg-Johnson et al. 2008; Vos et al. 2016). In particular, low back pain (LBP) and neck–shoulder region pain (NSP) are highly prevalent and experienced by the majority of people at some point in life. By definition, both LBP and NSP are non-specific symptoms without severe pathology and individuals recover within few weeks, yet recurrence is common (Guzman et al. 2008; Maher et al. 2017). LBP can also occur with pain radiating to the leg(s), which is a symptom with a less favorable outcome (Konstantinou and Dunn 2008). Sometimes frequent, continuous, or a high intensity of spinal pain leads to avoidance of physical activity due to perceived disability and catastrophizing behavior, which may result in prolonged and chronic pain (Crombez et al. 2012; Vlaeyen et al. 1995). Anticipatedly, the most effective non-pharmocological and prefered long-term treatment of LBP and NSP are exercise therapy and psychological treament (Babatunde et al. 2017; Ribaud et al. 2013; Sterling et al. 2019).

Recent reviews have also indicated that regular leisure-time physical activity (LTPA) may reduce the prevalence of both non-specific LBP (Alzahrani et al. 2019; Shiri and Falah-Hassani 2017) and radiating LBP (Shiri et al. 2016). In contrast, LTPA seems to protect from NSP only in previously pain-free individuals (Palmlof et al. 2016). Interestingly, some studies have suggested that both sedentary behavior and vigorous activities may cause spinal pain (Heneweer et al. 2011). Thus, the associations of LTPA with LBP and NSP are still unclear. When it comes to specific sport activities , some may protect against spinal pain whereas some may provoke it (Daniels et al. 2011; Noormohammadpour et al. 2018; Trompeter et al. 2017). Reviewed evidence on population-based interventions has indicated that a combination of strengthening with either stretching or aerobic activities participated in 2–3 times weekly may be recommended for the prevention of LBP (Shiri et al. 2018). Overall, the role of participation in a diversity of sport activities in LBP and NSP is unknown.

While the dose of LTPA has been the primary interest in earlier investigations, the diversity of sport activities, in terms of quality and quantity, has received little attention. Previously, only a few population-based studies have addressed the diversity of sport activities as a correlate or determinant of LTPA or spinal pains. Even fewer studies have used a longitudinal study design and, to our knowledge, none have used a twin study design to examine the association between the diversity of sport activities and spinal pain. Participation in a diversity of sport activities compared to single sport activity could provide additional health benefits, such as better sustained LTPA levels and less troublesome spinal pains, yet evidence is scarce.

2 REVIEW OF THE LITERATURE

2.1 LEISURE-TIME PHYSICAL ACTIVITY

Physical activity is a behavior that consists of several components and occurs in various contexts, making it difficult to define unambiguously. Moreover, physical activity is often mixed with exercise, sports, and physical fitness. However, the most common definition for physical activity is "any movement produced by skeletal muscles resulting in energy expenditure" (Caspersen et al. 1985). Generally, physical activity can be divided into broad components including occupational, transport, domestic, and leisure time (Khan et al. 2012; Strath et al. 2013), the last being the focus in this thesis.

By definition, leisure-time physical activity (LTPA) includes physical activities participated in during leisure time that are voluntarily performed and non-essential for daily living, including exercise, sport, and unstructured recreation (Khan et al. 2012; "Physical Activity Guidelines Advisory Committee Report, 2008. To the Secretary of Health and Human Services. Part A: Executive Summary" 2009). The context of LTPA is considered to have three aspects: 1) type, which refers to a specific activity (e.g., ice hockey, walking), 2) modes, including team sports, individual sports, organized sports without a competitive nature, and non-organized or informal physical activity, and 3) settings, which may be organization-based such as schools, clubs and leisure centers, or neighborhood-related such as home, street or park (Eime et al. 2013). Thus, LTPA may or may not include exercise and/or participation in sport(s), since they are considered subcategories of LTPA (Strath et al. 2013). Exercise is defined as planned, structured, and repetitive physical activity with the objective to improve or maintain physical fitness (Caspersen et al. 1985). Sport is considered as a subcategory of both physical activity and exercise since it has a defined goal and traditionally involves a competitive nature and participants (individuals or teams) who follow a common set of rules or expectations (Khan et al. 2012). Sport is also used as a synonym for sport disciplines, games or events (in track and field). In this thesis, the term "sport activities" refers to both competitive and recreational sports participated in during leisure time (Malina 1996).

Physical fitness is closely related to physical activity, but it is neither a subcategory nor a synonym. Physical fitness is defined as "the ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies" (President's Council on Physical Fitness and Sports 1971). Physical fitness can be measured by its health-related components: cardiorespiratory fitness, muscular strength and endurance, body composition, flexibility, and neuromotor fitness (Caspersen et al. 1985). The relationship between physical activity and physical fitness is often considered to be a positive correlation or a dose–response relationship between dose of physical activity and achieved health-related changes. Accordingly, some of the health benefits related to physical activity are transmitted through improved fitness that tends to have a stronger correlation with health outcomes. Moreover, the magnitude of the dose–response relationship varies considerably between individuals (Blair et al. 2001). Familial factors (such as genes and family environment) have been shown to have a significant contribution to the variability of the training response which may also be largely determined by the pretraining level of the phenotype, e.g., blood pressure (Bouchard and Rankinen 2001). Thus, even though the measurement of physical fitness is rather objective, it may sometimes represent the characteristics of an individual rather than the outcomes of physical activity participated in.

2.1.1 MEASUREMENT OF PHYSICAL ACTIVITY

Physical activity is related to substantial health benefits and, thus, a great deal of research has focused on quantifying the dose of physical activity required to achieve the health benefits. Typically, the dose of physical activity comprises frequency, intensity, and duration of physical activity (Haskell et al. 2007). Frequency equals the number of physical activity events over a specific period of time, duration equals the length of time consumed per a single physical activity event (or bout), and intensity describes the physiological effort specific to the type of physical activity participated in (Warren et al. 2010).

The dose of physical activity can generally be measured with subjective and/or objective techniques. Nevertheless, accurate assessment of all physical activity components simultaneously remains a challenge. Subjective methods comprise different types of self-reports including questionnaires, interviews, and diaries which may gather records of current physical activity or recalls of previous physical activity (Warren et al. 2010). Objective methods include the gold standard methods to capture energy expenditure, i.e., direct and indirect calorimetry including the doubly labelled water technique, as well as the recent large increase in the use of motion sensors (pedometers and accelerometers) and heart rate monitors (Vanhees et al. 2005). The choice of technique is largely dependent on the study design, as well as feasibility and costs.

The objective techniques are considered more accurate since they record physical activity or energy expenditure in real time (Strath et al. 2013) and differ less in terms of validity and reliability compared to subjective methods (Dowd et al. 2018). The gold standard technique, direct calorimetry, that measures energy expenditure as heat production or heat loss, however, is rather laborious and not feasible in practice. Similarly, the indirect calorimetries that measure heat production or energy expenditure by oxygen consumption and/or carbon dioxide production, such as the doubly labelled water technique, are mostly used to validate other more practical objective and subjective methods (Vanhees et al. 2005). Due to recent technological improvements, the use of motion sensors and heart rate monitors has increased, although simultaneous recording of large populations is still quite expensive (Dowd et al. 2018). By definition, motion sensors record the body motion by measuring the acceleration in one to three dimensions. Pedometers are able to record only the vertical movements and, thus, are good at recording walking and running-related sport activities but poor at recording non-vertical movement or the intensity of physical activity (Vanhees et al. 2005). Newer accelerometers can record movements in several planes and better capture different types of sport activities, but the detection of complex movements involving the upper body, cycling or graded terrains is still limited. Generally, acceloromenter-based data has acceptable validity to estimate overall physical activity and become increasingly popular in research, especially in the high-income countries (Guthold et al. 2018; Vanhees et al. 2005). In contrast to motion sensors, heart rate monitors are good at recording the intensity of physical activity since heart rate indicates the intensity of the relative stress to the cardio-respiratory system during physical activity (Vanhees et al. 2005). During rest and at lower intensities of physical activity, however, heart rate may be influenced by factors such as caffeine, body position, or smoking (Livingstone 1997). Due to the possible confounding factors, individual level data is unreliable (Davidson et al. 1997), but in epidemiological settings the data is considered to be more valid (Livingstone 1997). Overall, the most comprehensive and feasible objective record on physical activity may be captured with a combination of accelerometer and heart rate monitoring. However, if only these techniques are used, the type of physical activity participated in will remain unknown (Strath et al. 2013).

The subjective techniques have maintained their position in the population-level research of physical activity, and questionnaires remain the most popular, inexpensive, and feasible technique to study large samples (Guthold et al. 2018; Vanhees et al. 2005; Warren et al. 2010). Survey techniques can be categorized as follows: self-report questionnaires, interviewer-assisted questionnaires, proxy-report questionnaires, and diaries. The obvious limitations of these techniques are response and recall biases since the interpretation of the questions and conception of physical activity participation are subjective. The response bias generally describes the tendencies of individuals to respond inaccurately or falsely to questions (under- or overreportation), whereas recall bias is related to the function of memory, which may be eased with a shorter recall period. Evidently, age (e.g., young children and elderly) and cultural background may also influence the ability to respond (Warren et al. 2010). Recently, the increased use of computer-based surveys has made data collection more effective, reduced the number of coding errors and missing answers, as well as made it possible to skip unnecessary questions, making the response process more fluent (Vanhees et al. 2005). Although many physical activity questionnaires have acceptable reliability, their validity is moderate at best (Helmerhorst et al. 2012) and varies, especially when estimating the intensity of physical activity (Dowd et al. 2018). Ideally, all survey techniques should be validated by objective methods; however, this is not always feasible due to differences and low correlations in measurements. In the future, subjective methods are suggested to be combined with appropriate objective measures to reduce the variability in the validity and reliability of physical activity data (Dowd et al. 2018; Haskell et al. 2007).

When lacking accelerometer-based data, one common way to estimate the intensity of physical activities in epidemiological settings has been using metabolic equivalents of task, i.e., MET values, to describe the energy expenditure during a specific activity (Ainsworth et al. 2011). The MET values are multiples of the resting metabolic rate describing the increased energy consumption compared to rest caused by physical activity (McArdle et al. 2001). One MET has been defined to equal the oxygen consumption when sitting at rest, i.e., approximately 3.5 ml of oxygen per 1 kg of body weight multiplied by minutes (Jetté et al. 1990).

$$\boxed{1 \text{ MET} = 3.5 \text{ ml } O_2/\text{min/kg} = 1 \text{ kcal/kg/h}}$$

Thus, an activity of two METs doubles the metabolism compared to the resting state. Generally, MET values < 1.6 are related to sedentary activities with little additional movement to the resting state, 1.6–2.9 METs are considered light activity which does not cause a noticeable change in breathing rate, 3–5.9 METs equal moderate activity that can be performed while maintaining a conversation and values > 6 METs are defined as vigorous activity which does not allow sustained conversation and can be sustained only up to about 30 minutes (Norton et al. 2010). MET values are especially useful when calculating an overall index for physical activity by multiplying the frequency, intensity (MET value) and duration of physical activity. This type of MET index (e.g., MET-min/day or MET-h/week) can be calculated for any of the physical activity domains (occupational, transport, domestic, and leisure) or for overall physical activity. The Compendium of Physical Activity was developed in 1993 and last updated in 2011 to provide a comprehensive list of MET values for self-reported physical activities including occupational, transport, domestic, and leisure activities (Ainsworth et al. 2011). Of note is that MET is only an estimate of energy expenditure related to specific physical activities, since individuals’ characteristics including age, size and body composition are not taken into account, potentially leading to over- and underestimations of energy consumption in heterogeneous populations (Kozey et al. 2010).

2.1.2 PHYSICAL ACTIVITY RECOMMENDATIONS AND LEVELS

The American and Finnish physical activity guidelines have been recently updated ("Liikkumalla Terveyttä – Askel Kerrallaan. Viikoittainen Liikkumisen Suositus 18–64-Vuotiaille." 2019; Piercy et al. 2018), broadening the recommendations of the World Health Organization (WHO) from 2010. For children aged 5–17 years, the WHO recommends 60 minutes of moderate to vigorous physical activity (MVPA) daily, most of which should be aerobic, but muscle- and bone-strengthening activities (playing games, running, turning or jumping) should also be performed 3 times a week. For healthy adults aged 18–64 years, the WHO recommends aerobic exercise for 150 minutes at moderate intensity or 75 minutes at vigorous intensity or an equivalent combination weekly (equal to 1.5 MET-h/day) in bouts of at least 10 minutes to gain significant health benefits. In addition, recommendations include participation in muscle strengthening and balance/agility/flexibility-improving activities at least twice a week. Older and disabled adults are encouraged to follow the same recommendations to the best of their abilities (World Health Organization 2010). The recently updated American guidelines for physical activity have utilized the growing body of evidence from studies with objective measurement of physical activity. The guidelines are similar to WHO recommendations but include more specific guidelines for a variety of population groups, e.g., pregnant women, and emphasize that additional benefits can be achieved with more physical activity (Piercy et al. 2018). Thus, adults are recommended to do aerobic physical activity for at least 150–300 minutes at moderate intensity, or 75–150 minutes at vigorous intensity or an equivalent combination, weekly along with muscle strengthening activities at least twice a week. Generally, the American guidelines suggest that moving more and sitting less will benefit nearly everyone, thus, the requirement to engage in physical activity in bouts of at least ten minutes has been removed according to the updated evidence (Powell et al. 2011). The Finnish physical activity guidelines for adults have also been updated largely following the American example. They include recommendations for moving around whenever possible, taking regular breaks while doing stationary work, and also sleeping enough to improve recovery ("Liikkumalla Terveyttä – Askel Kerrallaan. Viikoittainen Liikkumisen Suositus 18–64-Vuotiaille." 2019). However, the Finnish guidelines have kept the amount of moderate and/or vigorous intensity physical activity at a similar level to WHO recommendations. For Finnish children aged 8–17 years, a work group recommends 90 minutes of physical activity daily and at least half of it should be at moderate to vigorous intensity. Children and adolescents are recommended to get out of breath daily, strain their muscles three times a week, and move whenever possible including school day breaks, transportation, choosing stairs and avoiding long-term sitting ("Fyysisen Aktiivisuuden Suositus Kouluikäisille 7–18-Vuotiaille" 2008).

Notably, all the physical activity guidelines are focused on LTPA since it has become the greatest contributor to overall physical activity, while occupational, transportation, and domestic activities are becoming automated (Borodulin et al. 2012; Hallal et al. 2012). In 2012, physical inactivity was considered the fourth leading cause of death worldwide and thus called a pandemic, demanding global action for public health (Kohl 3rd et al. 2012). Globally, 31.1% of adults (>15 years) were physically inactive, i.e., not achieving 30 minutes of moderate-intensity activity on five days a week, or 20 minutes of vigorous-intensity activity on three days a week, or an equivalent combination. Moreover, 80.3% of 13–15-year-olds did not engage in 60 minutes of MVPA daily in 2012. Among both adults and adolescents, men were more likely to be active than women (Hallal et al. 2012). During the follow-up in 2016, 23% of adults (aged >18 years) did not achieve the updated recommendation, i.e., 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity activity a week, or an equivalent combination, regardless of the weekly frequency. The positive change between 2012 and 2016 has been proposed to mostly reflect the updated recommendations for adults, which are easier to achieve. Accordingly, 80% of school-going adolescents (aged 11–17 years) did not achieve the unchanged recommendation of 60 minutes or more of MVPA daily (Sallis et al. 2016). Between 2012 and 2016, the data availability increased, from 122 countries to 146 countries, and thus represented 93.3% of the world's population in 2016. Later on, the global age-standardized prevalence of physical inactivity was estimated to be 27.5% in 2016, which was based on more comprehensive data on adults from 168 countries (Guthold et al. 2018). No significant changes were detected in global physical actitvity levels between 2001 and 2016. In the future, more objective data on physical activity is expected to be used in both the creation of physical activity recommendations, as well as surveillance of the global physical activity levels (Guthold et al. 2018).

The call for action to increase physical activity levels globally is easy to justify with health benefits, as well as with the recently quantified substantial economic burden related to inactivity (Ding et al. 2016). Not only is regular physical activity associated with, e.g., a lower risk of diabetes, depression, and several cancers, but also with a lower risk of all-cause mortality and improved quality of life, physical function, and cognition, as presented in Table 1 (Piercy et al. 2018; World Health Organization 2010). In 2013, the costs of physical inactivity were 53.8 billion (all costs were converted to international $) for healthcare systems and 13.4 million disability-adjusted life years for societies worldwide (Ding et al. 2016). In the future, besides behavioral studies focusing on individuals, a system-wide approach concentrating on populations and the complicated association between the correlates of physical inactivity should be used as a way to move forward (Bull and Bauman 2011; Kohl 3rd et al. 2012).

A great effort has already been made to explore the factors affecting physical activity levels. These factors comprise individual-level factors and broader ecological models including the social and physical environment

(Bauman et al. 2012). In general, males are more active than females and children are more active than adults. Previous tracking studies and more recent trajectories based on objective measurements have showed that the decline of physical activity starts already around the age of school entry and continues through adolescence to adulthood. However, the decline may be inverted later in life (Lounassalo et al. 2019; Reilly 2016; R. Telama 2009).

Table 1 The health benefits related to regular participation in physical activity among adults and older adults modified from Piercy et al., 2018 and World Health Organization, 2010.

Lower risk of	**Improved**
all-cause mortality	quality of life
cardiovascular disease (including heart disease and stroke) and related mortality	cardiorespiratory and muscular fitness
hypertension	physical function
type 2 diabetes	body composition
adverse blood lipid profile	weight loss, particularly when combined with reduced calorie intake
weight (re)gain	weight maintenance
falls and fall-related injuries (older adults)	bone health
dementia (including Alzheimer disease)	cognition
anxiety	sleep
depression	
cancers of the bladder, breast, colon, endometrium, esophagus, kidney, lung, and stomach	

In the first Lancet series on physical activity, Bauman et al. (2012) have reviewed the correlates of physical activity. Earlier physical activity in childhood and adulthood seems to be a determinant of current physical activity. Moreover, health status and self-efficacy are known determinants of physical activity among adults. Family and general social support are important for physical activity among both children and adolescents. In adulthood, higher education level, ethnic origin (white) and social support have shown positive correlations with physical activity level, whereas overweight and subjectively perceived effort have shown inverse correlations (Bauman et al. 2012). Occupational activity has been directly associated with LTPA since white-collar/professionals show higher LTPA levels compared to blue-collar workers. In contrast, total physical activity including occupational, transport, domestic, and leisure time activity, tends to be higher among blue-collar workers (Kirk and Rhodes 2011). Stress has been identified as an inverse determinant of physical activity, whereas action planning is a determinant for the initiation of physical activity (Bauman et al. 2012). Furthermore, motivational factors including good health, mastery, physical fitness, body image, appearance, enjoyment and psychological state are associated with LTPA participation (Aaltonen et al. 2014; Allender et al. 2006). Expanding evidence demonstrates the significant contribution of genetic factors to physical activity which, however, vary strongly over age and lack defined genetic mechanisms underlying the behavior (Lightfoot et al. 2018). Increasing importance has also been given to environmental factors, ranging from the nearby surroundings to national and global health policies. Among children and adults, leisure-time and overall physical activity levels have been related to factors such as neighborhood walkability, transportation environment, and proximity to recreation facilities and locations (Bauman et al. 2012; Ding et al. 2011). Both multidisciplinary and multi-professional interventions tailored for target populations regarding the range of factors influencing physical activity levels are well-founded in recommendations promoting physical activity.

2.1.3 DIVERSITY OF LEISURE-TIME SPORT ACTIVITIES

This thesis focuses on the diversity of LTPA and uses the term "diversity of leisure-time sport activities" to describe the range of different sport activities, with and without a competitive nature, participated in during leisure-time. Later on, the term is shortened to diversity of sport activities. Since studies with similar objectives to this thesis are scarce, established terminology is lacking. However, studies with a similar ideation have been summarized in Table 2. One study used the term "sport disciplines" to refer to different types of sports but aiming to separate them from "competitive" sports (Rottensteiner et al. 2017), whereas another study used the term "physical activities" (Kjonniksen et al. 2008). Most of the previous studies have used the term "sports" despite the competitive or non-competitive nature of the physical activity participated in (Aarnio et al. 2002; Belanger et al. 2015; Cleland et al. 2012; Dovey et al. 1998; Jose et al. 2011; Tammelin et al. 2003). Only one of the previous studies has used the term "diversity of sports" (Jose et al. 2011).

In this thesis, the diversity of sport activities is examined both in a quantitative and qualitative way, i.e., as the number of sport activities participated in and the types of sport activities participated in. As far as I know, only a few population-based studies have considered the number of sport activities participated in during adolescence or adulthood (Borodulin et al. 2012; Rottensteiner et al. 2017). Some of these studies have used the number of sport activities as a categorical variable with two or three categories, the uppermost being three or more sports (Borodulin et al. 2012; Cleland et al. 2012; Engström 2008; Jose et al. 2011), whereas the others have reported a simultaneous decline in the mean number of sport activities participated in and physical activity level (Dovey et al. 1998; Kjonniksen et al. 2008). In New Zealand, from age 15 to 18 years, the mean number of activities decreased from 7 to 3 among boys and from 6 to 3 among girls (Dovey et al. 1998). In Norway, from age 15 to 23 years the mean number of physical activities participated in decreased from 7.5 to 4.0 among men and from 5.7 to 3.5 for women (Kjonniksen et al. 2008). Thus, the quantity of sport activities seems to decrease during adolescence and in the transition to adulthood.

Compared to the quantity, the quality of sport activities has been assessed more often in various populations and the study designs range from nationwide studies (Bennie et al. 2019; Bennie et al. 2017; Bennie et al. 2016) to very specific athlete samples such as sky divers (Nilsson et al. 2013). Strath et al. define that the mode of physical activity may refer to specific activities such as walking, swimming, or ice hockey, but also to the physiological or biomechanical demands/types of the activity such as aerobic activity, strength or balance training (Strath et al. 2013). Some studies have considered either participation in specific activities (Kjonniksen et al. 2008; Tammelin et al. 2003) or physiological types of activities (Bennie et al. 2019), whereas some have considered both simultaneously (Aarnio et al. 2002; Rottensteiner et al. 2017). Additionally, factor analysis has been used to derive different categorizations for types of sport activities (Auvinen et al. 2008; Belanger et al. 2015). Most of the studies regarding participation in different types of sport activities, however, have focused on adolescent and/or athlete samples.

Notably, the physical activity recommendations for the general population clearly indicate that one should participate in different types of physical activity, i.e., moderate to vigorous intensity aerobic activity and muscle-strengthening activities and/or balance/agility/flexibility-improving activities weekly (World Health Organization 2010). Yet, the recommendation to participate in several types of physical activity is met by even fewer individuals than the most acknowledged recommendation for aerobic activity. In the Finnish population-based "Regional Health and Well-being Study" in 2013–2014, the Finnish recommendation for aerobic MVPA was met by around 31% of Finnish adults (18–98 years), whereas the total recommendation also including muscle strengthening and/or balance enhancing activity was met by only around 11% (Bennie et al. 2017). In the U.S. 2015 "Behavioral Risk Factor Surveillance", around 30% of American adults (18–80 years) met the WHO recommendation (World Health Organization 2010) for MVPA and around 20% for both MVPA and muscle-strengthening activity. In the National Nutrition and Physical Activity Survey (a subcomponent of the Australian Health Survey) 2011–12, around 53% of Australian adults (18–85) met the recommendation for MVPA, whereas only 15% met the recommendation for both MVPA and strength-training (Bennie et al. 2016). The differences between populations may partly be due to the use of different questionnaire items and physical activity recommendations. However, in at least two out of three populations, those with poorer self-rated health, older age, female sex, lower education rate and being a current smoker or classified as overweight or obese were less likely to meet the recommendation for both MVPA and muscle-strengthening activity (Bennie et al. 2019; Bennie et al. 2017; Bennie et al. 2016). Furthermore, in a cross-sectional analysis adjusted for, e.g., self-rated health and smoking, meeting the total recommendation, compared to meeting only aerobic or muscle-stregthening or none, was associated with the lowest prevalence ratios of 12 common chronic health conditions including diabetes, coronary heart disease, hypertension, and depression (Bennie 2019). Overall, only a few studies have addressed the recommendation to participate in not only MVPA but also in different types of activities, including muscle-strengthening (Bennie et al. 2016; Evenson et al. 2016; Liangruenrom et al. 2018; Rhodes et al. 2017), and/or balance- and coordination-improving activities (Strain et al. 2016).

To date, the health benefits related to the level of LTPA are rather well documented, but little is known about the benefits of participation in a diversity of sport activities. Among adolescents, some studies have explored the associations between participation in a single sport or diversity of sport activities and musculoskeletal pain (Auvinen et al. 2008; Fabricant et al. 2016; Farahbakhsh et al. 2018; Guddal et al. 2017), whereas the few adult studies have focused on obesity (Lin et al. 2019; Rottensteiner et al. 2017). One study has found that participation in a diversity of sport activities, both quantitatively and qualitatively, is related to smaller waist circumference in young adults (Rottensteiner et al. 2017). Another study has examined what kind of sport activities could modify the genetic risk of obesity and found that regular jogging had the most consistent and significant interaction with the genetic risk score of obesity. Interestingly, genetic effects on body mass index (BMI) were also attenuated among those who participated in mountain climbing, walking, exercise walking, international standard dancing, and a longer practice of yoga (Lin et al. 2019). In the future, more studies concentrating on the diversity of sport activities are required to improve the level of knowledge on potential additional health benefits.

Table 2 Summary of population-based prospective cohort studies addressing the effects of the diversity of sport activities on future leisure-time physical activity.

Author, (year)	**Country**	**Study design**	**Exposure(s)**	**Outcome**	**Key findings**
Dovey et al., (1998)	Australia	775 members of a birth cohort enrolled in the Dunedin Multidisciplinary Health and Development Study were interviewed during 1987–1988 (age 15) and 1990–1991 (age 18)	Time spent in physical activity, participation rates and time in specific sports and similar physical activities	Time spent in physical activity, participation rates and time in specific sports and similar physical activities	Both the time spent in physical activity and the number of sport activities participated in decreased from age 15 to 18, the latter from 7 to 3.
Aaron et al., (2002)	USA	782 adolescents recruited from a single suburban school district near Pittsburgh aged 12 to 15 years at baseline who were annually followed for 4 years	The Modifiable Activity Questionnaire for Adolescents including 26 common recreational and leisure time activities and additional self-reported activities with participation at least 10 times during the past year, the frequency and duration of participation in each activity during the past year	Overall LTPA summed from all activities, stability of specific activities and stability of different types of activities: team vs individual, light and moderate intensity vs vigorous intensity, year-round vs seasonal	During the 4 years, physical activity declined by 26% which was primarily due to decrease in the number of reported activities. The probability to maintain participation in a specific activity was low to moderate.
Aarnio et al., (2002)	Finland	2934 adolescents (54% female) from a Finnish twin cohort study who replied to three questionnaires with two identical physical activity questions at ages 16, 17, and 18 between 1991–1996	The frequency of LTPA at age 16, 17 and 18, the types of sports participated in outside school (a multiple-choice question) and participation in organized or competitive sports at age 17. The type of sports was divided into three groups: aerobic, power, and others.	Persistent exerciser, i.e., participation in physical activity 4–5 times a week in all three questionnaires	Participation in several different types of sports and in organized sports related to a higher stability of LTPA. Participation in cross-country skiing, jogging and body building in boys and participation in ball games in girls related to higher proportions of persistent exercisers.
Tammelin et al., 2003)	Finland	7794 individuals from the Northern Finland 1966 birth cohort responded to mailed questionnaires regarding physical activity status at age 14 and 31	In adolescence, individuals reported frequency of sport participation after school hours and the main types of sports participated in, coded into 20 groups.	In adulthood, four categories based on the frequency, intensity, and duration of physical activity participated in: very active, active, moderately active, and inactive	Participation in the intensive endurance sports and some sports that require and encourage diversified sports skills in adolescence were related to higher physical activity level in adulthood.

Engström et al., (2008)	Sweden	91 randomly selected Swedish school classes in Year 8 (age 15) from four different counties were contacted in 1968. The most recent 7th follow-up took place in 2007 when 1518 responses were received from individuals at age 53	Membership of sports clubs, experience on 7 leisure-time ‘sports’ and time spent on leisure-time sports in a normal week in May and February at age 15. “Sport breadth” variable summarized the experiences of (1) skiing, (2) track and field/jogging/orienteering, and (3) gymnastics/dance/ballet with a scale 0–3.	Non-exercisers and exercisers who engaged in more strenuous exercise, such as rapid walking, jogging, swimming, working out or other equivalent forms of exercise once a week	When breadth of sport experience was used as a covariate, neither sports club membership nor the time spent on sporting activity at age 15 was associated with exercise habits in middle age. Sport breadth was significantly associated with later exercise habits.
Kjonniksen et al., (2008)	Norway	630 subjects from The Norwegian Longitudinal Health Behaviour Study, followed from age 13 to 23 between 1990–2000 with 7 follow-up questionnaires	Participation in global LTPA, outdoor recreational activities, and specific types of leisure-time physical activities	Participation in global LTPA, outdoor recreational activities, and specific types of leisure-time physical activities	General decline in LTPA during the transition from adolescence to adulthood, moderate positive association between participation in several physical activities in adolescence and physical activity in adulthood.
José et al., (2011)	Australia	2048 individuals participated in the Australian Health and Fitness Survey in 1985 at the age of 7–15 and completed the historical leisure activity questionnaire (HLAQ) in 2004–2006	List of up to 6 sports participated in during the past year in and outside school dichotomized to playing 3 or more or playing less than 3 sports	Physical activity measured retrospectively with HLAQ between the ages 15 and 29 years and categorized as persistently active, variably active or persistently inactive during the transition from adolescence to adulthood.	Participation in 3 or more sports at school or outside school at the age of 7 to 15 years was significantly associated with persistent physical activity during the transition from adolescence to adulthood.
Cleland et al., (2012)	Australia	2201 participants from the Australian Schools Health and Fitness Survey who were surveyed in 1985 at the age of 9–15 years and in 2004–2006 at the age of 26–36	Leisure activity as self-reported frequency and duration of discretionary sport and exercise, transport activity, school sport and physical education in the past week, and number of sports played in the past year	The long International Physical Activity Questionnaire and/or a Yamax pedometer	In general, LTPA in childhood was a poor predictor of physical activity in adulthood, yet the number of sport activities during the past year positively predicted adult physical activity among younger males and transport activity among younger males and older females.

Borodulin et al., (2012)	Finland	718 individuals aged 30–80 who participated in the national Mini-Finland Health Survey in 1978–1980 and a follow-up in 2001	LTPA in 1978–80: 1) only a little physical exercise, 2) physical exercise in connection with other hobbies or irregularly, and 3) regular physical exercise. Those who participated in regular exercise were asked to list the most common types of activities they engaged in. For the analyses, four groups were created "no activity", "irregular activity", "1–2 types of regular activity", and "3 or more types of regular activity".	LTPA in 2001: Inactive (in my leisure time I read, watch TV and do other activities in which I do not move much and do not strain me physically) or physically active (in my leisure time I walk, cycle, and move in other ways at least 4 hours (moderate intensity) or at least 3 hours (vigorous intensity) per week, or regularly practice several times a week for competition (very vigorous intensity)	Participation in 3 or more types of regular activity at baseline had the strongest association with being physically active at the follow-up, but also participation in 1–2 types of regular activity or irregular activity compared to no activity had a significant positive association with being physically active later in life.
Belanger et al., (2015)	Canada	At baseline, 673 (54% female) adolescents, aged 12–13 years reported participation in 29 physical activities every 3 months over 5 years (1999–2005). In follow-up, at age 24 physical activity level was reported (2011–12).	The number of years participating in each grouping identified with factor analysis: "sports" including ice hockey, ice skating, football, roller blading/skateboarding, basketball, soccer, boxing and baseball; "fitness and dance" including jazz dance, dancing, gymnastics and games; and "running" including running and mixed walking (e.g., hiking and walking mixed with jogging)	Physical activity level (MET-min/week) at age 24 surveyed with Physical Activity Questionnaire short form	The number of years participating in running or sports (but not in dance and fitness) during adolescence was associated with higher physical activity level in adulthood. For running, no threshold was detected, whereas for sports the association was only seen with 4- or 5-years participation.

LTPA=leisure-time physical activity, HLAQ=Historical Leisure Activity Questionnaire, MET=metabolic equivalent of task

2.2 DIVERSITY OF SPORT ACTIVITIES AND LEISURE-TIME PHYSICAL ACTIVITY

To achieve the numerous health benefits of physical activity (Table 1), participation needs to be regular and continued throughout the lifetime (Piercy et al. 2018; Rangul et al. 2012; World Health Organization 2010). Age, however, has an inverse correlation with physical activity level, whereas previous physical activity participation has a positive correlation with present physical activity (Bauman et al. 2012). Several studies have further investigated the stability of physical activity tracking, defined as the maintenance of a person's relative rank or position within an activity group over time (Malina 2001; Telama 2009). Overall physical activity tracking ranges from low to moderate, being somewhat higher for males than females and higher in adulthood compared to childhood (Telama 2009). Naturally, when the follow-up time increases, the tracking coefficients tend to decrease (van der Zee et al. 2019). In addition to the tracking studies, physical activity trajectories using multiple measurement points have described the development of physical activity behavior over longer time periods, and most have commonly identified three to four subgroups, such as: persistent physical activity, decreasers from moderate levels of physical activity, consistent low activity, and inactivity (Lounassalo et al. 2019; Pate et al. 2019). Regarding the intensity of physical activity, rather similar declines in MVPA occur among both sexes during adolescence, but girls are consistently less active (Pate et al. 2019; Reilly 2016). A longitudinal study (SPEEDY) following British children from age 10 to 14 has shown that a relatively large share of the decrease in MVPA consists of weekend and out-of-school-time activities (Brooke et al. 2016). Furthermore, the increasing sedentary behavior during adolescence seems to displace light-intensity activities (Reilly 2016). Specifically, increasing television viewing has been related to decreasing physical activity trajectories (S. Kwon et al. 2015). Reviewed evidence shows that inactivity is maintained more often than persistent activity, and the decline which includes all intensities of physical activity is most consistent in childhood and in adolescence during leisure time (Lounassalo et al. 2019; Pate et al. 2019; Telama 2009).

Several studies concentrating on the transition from childhood to adolescence have found that sports participation declines simultaneously with physical activity level (Aarnio et al. 2002; Aaron et al. 2002; Baldursdottir et al. 2017; Dovey et al. 1998; Lounassalo et al. 2019; Manz et al. 2016; Robertson-Wilson et al. 2003; Turner et al. 2015). Accordingly, sustained sport participation may become a critical contributor to physical activity level during adolescence (Lagestad et al. 2018; Payne et al. 2013; Pfeiffer et al. 2006; van Mechelen et al. 2000). In support of this, two longitudinal studies have reported a positive association between the number of sport activities and physical activity level at the end of adolescence (Aarnio et al. 2002; Robertson-Wilson et al. 2003), whereas another two studies have connected the decreasing number of sport activities to the decline in physical activity during adolescence (Aaron et al. 2002; Dovey et al. 1998). Somewhat opposing results has been detected in a sample of British children (SPEEDY) where the change of variety in sports participation had no association with the change of MVPA or total physical activity in the transition to adolescence (Brooke et al. 2014). A few studies indicate that the decrease in sport participation happens especially among girls (Aarnio et al. 2002; Manz et al. 2016; Turner et al. 2015), which is concerning since girls are suggested to have a reduced length of involvement in sports due to later entry and earlier drop-out (Sabo 2009). One study has also implied that adolescent girls may achieve physical activity mostly through sports (Pfeiffer et al. 2006), whereas another study among girls has shown a transition from organized sports to non-organized physical activity without significant decreases in physical activity levels during adolescence (Eime et al. 2016). Noteworthy is that the decline in sports participation between compulsory and secondary school has been related to higher BMI among both sexes (Turner et al. 2015) and to an increase in depressive symptoms, especially in girls (Baldursdottir et al. 2017). This supports the notion of Eime et al. (2016) that the transition from structured sports to non-organized LTPA may effect social and psychological health among girls. Furthermore, ethnic background, rural/urban environment, family and neighborhood income seem to impact girls' participation in organized sports more than boys (Manz et al. 2016; Sabo 2009). Thus, especially girls may benefit from encouragement and easy access to opportunities to participate in different sport activities with the aim to increase their LTPA in adolescence and adulthood.

Compared with participation in organized sport activities, the role of free active play and self-organized or informal physical activity has been less-studied compared to the participation in organized sports (Cairney et al. 2018; Wiium and Säfvenbom 2019). A cross-sectional study among British children (from ages 5–15) who met the physical activity recommendation detected that active play is the largest contributor to overall physical activity, but it decreases with age while the contribution of walking and formal sports increases (Payne et al. 2013). Cairney et al. (2018) have addressed the role of free active play since it is essentially a discretionary choice with numerous benefits including the development of cognitive, physical, and emotional skills. Consistent with these findings, a Norwegian study implied that concurrent involvement in both organized sports and self-organized physical activity for at least an hour a week may be more developmentally beneficial than participating in only one modality for two hours a week (Wiium and Säfvenbom 2019). Overall, participation in several types and modes of physical activity, including both organized sports and informal LTPA (Eime et al. 2013), in adolescence seems beneficial and crucial in the maintenance of LTPA level.

The field of competitive youth sports, that aims for athlete development, has long been debated regarding the pros and cons of participation in a diversity of sport activities versus concentration on a single activity. The Developmental Model of Sport Participation, created in 1999 and continually updated, models athlete development and uses the term “early sampling” to describe participation in a diversity of sport activities in childhood (Côté and Vierimaa 2014). The model includes seven postulates that consider the role of sampling and deliberate play in sports participation, performance, and personal development during childhood. After two decades, the accumulated evidence implies that early diversification: 1) does not hinder elite sport participation in sports where peak performance is reached after maturation, 2) is linked to a longer sport career and has positive implications for long-term sport involvement, and 3) allows participation in a range of contexts that most favorably affects positive youth development (Côté and Vierimaa 2014). During the last decade, an increasing number of studies have also examined the opposite of sampling, i.e., youth sport specialization which is defined as intensive year-round training in a single sport at the exclusion of other sports (DiFiori et al. 2014; Jayanthi et al. 2013; Malina 2010; Myer et al. 2015). Specialization tends to be more common in individual sports (Pasulka et al. 2017) and among youth athletes with high socioeconomic status (Jayanthi et al. 2018). Even though the existing evidence is currently scant, mostly retrospective, and mainly derived from young American athletes, specialization in a single sport has been related to an increased risk of injuries, psychological distress, burnout and drop-out among young athletes (Côté and Vierimaa 2014; Crane and Temple 2015; Fabricant et al. 2016; Myer et al. 2015). In some sports with early intensive training such as ballet or gymnastics, the specialization may even compromise the growth and maturation of youth athletes (Malina 2010). Other potential risks of specialization include social isolation, overdependence, and manipulation (Malina 2010), which may be supported by the finding that youth specialization seems to be driven more by extrinsic factors, such as pressure from coaches and/or parents, than intrinsic motivation (Padaki et al. 2017). Accordingly, a review of drop-outs from organized sport in childhood and adolescence has identified five major contributing factors: lack of enjoyment, perceptions of competence, social pressures, competing priorities and physical factors (maturation and injuries) (Crane and Temple 2015). Thus, early sport specialization may lead to several unwanted outcomes without the achievement of sustained physical activity levels (Cairney et al. 2018). The potential health-harming effects of sport specialization have made the American physician organizations address the lack of evidence that early specialization leads to long-term success in sports, and recommend that early multisport participation may be beneficial rather than harmful for the development of elite-level skills (Brenner et al. 2007; DiFiori et al. 2014; LaPrade et al. 2016). As stated by the American Academy of Pediatrics: “The ultimate goal of youth participation in sports should be to promote lifelong physical activity, recreation, and skills of healthy competition that can be used in all facets of future endeavors" (Brenner et al. 2007). The current American physical activity guidelines highlight the importance of enabling and encouraging young people to participate in physical activities which are age appropriate, enjoyable, and offer variety (Piercy et al. 2018).

Participation in a diversity of sport activities early in life is also considered helpful to develop motor skills which may help to sustain physical activity through childhood to adulthood (Aaltonen et al. 2015; Cairney et al. 2018; Loprinzi et al. 2015). Stodden et al. (2008) have introduced a positive spiral of engagement suggesting that sustained physical activity results from high levels of motor competence, positive perceptions of competence, greater physical activity, and higher levels of health-related physical fitness, including healthy weight, which produces a positive feedback loop of engagement. On the contrary, the negative spiral of disengagement starting from low motor skill competency may lead to less physical activity, increased weight and obesity. The negative spiral may, however, be tackled with motor skills interventions, which a meta-analysis has found to be effective in increasing fundamental motor skills in children (Logan et al. 2012). The importance of early interventions is supported with the findings from a Finnish twin study where advanced motor development in childhood was positively associated with higher self-reported LTPA levels in young adulthood (Aaltonen et al. 2015). Another longitudinal Finnish study showed that childhood participation in intensive endurance sports and sport activities that improve motor skills via various methods had a positive association with physical activity levels in adulthood (Tammelin et al. 2003). Some sport activities, such as walking and running, are suitable for most people without specific requirements, whereas, e.g., downhill skiing and skating require diverse motor skills and, thus, may be more difficult to start in adulthood (Rinne et al. 2007). Futhermore, in support of developing diverse motor skills during childhood and adolescence are the studies summarized in Table 2 that have found a positive association between the quantity of sport activities in adolescence and physical activity in adulthood (Belanger et al. 2015; Cleland et al. 2012; Engström 2008; Jose et al. 2011; Kjonniksen et al. 2008; Robertson-Wilson et al. 2003). Thus, the benefits of diversified sport participation in childhood and adolescence seem to carry over to adulthood.

While physical activity seems to further decline in the transition from adolescence to young adulthood (Corder et al. 2019; Dumith et al. 2011), it stabilizes in middle adulthood (Caspersen et al. 2000; Lounassalo et al. 2019; van der Zee et al. 2019). Despite the declining trajectories, individuals' physical activity tracking shows a moderate to high stability through the transition to adulthood (Li et al. 2016; Telama et al. 2014), i.e., those who are highly active in adolescence tend to be highly active in adulthood and those with the lowest activity levels are the same individuals in adolescence and adulthood. Based on earlier evidence, the decline concerns especially regular vigorous-intensity activity, especially among males who have higher vigorous-intensity participation in adolescence (Caspersen et al. 2000; Hallal et al. 2012; Sallis et al. 1996). In addition, strengthening and stretching patterns have shown large declines in young adulthood (Caspersen et al. 2000). A recent Dutch study concentrating on leisure-time exercise through the lifetime determined physical activity tracking in six different domains: team-based versus solitary activities, competitive versus non-competitive activities, and externally-paced versus internally-paced activities (van der Zee et al. 2019). The decline in overall physical activity was largely due to decreasing participation in competitive and team-based activities, the latter surprisingly decreasing even more. Previous evidence has similarly indicated the significant contribution of team-based activities to physical activity in adolescence (Aarnio et al. 2002; Sallis et al. 1996), but also detected positive associations between participation in the same ball games during adolescence and adulthood (Tammelin et al. 2003). Several studies have suggested that participation in intensive endurance sports such as running, orienteering, cross-country skiing, and track and field during adolescence predicts a high level of physical activity in adulthood (Belanger et al. 2015; Engström 2008; Mäkinen et al. 2010; Tammelin et al. 2003; Telama et al. 1997). Of note is that sustained participation in intensive, i.e., vigorous, endurance sports, e.g., running, even less than one hour per week increases the current LTPA level considerably more compared to light intensity activities. Moreover, Sallis et al. (1996) have suggested that running may have a special role as an easily transferable skill between different sport activities. Running has shown benefits in aerobic fitness, cardiovascular function at rest, running performance, metabolic fitness, adiposity and postural balance (Oja et al. 2015), which may further ease sustained participation in physical activity (Stodden et al. 2008). Thus, acquired participation in vigorous endurance sports may aid to sustain LTPA levels from adolescence to adulthood.

The role of organized sport participation in the transition from adolescence to adulthood is unclear. Somewhat surprisingly, sport participation in young adulthood seems to be less common among those who had a drop-out of sports in childhood compared to those who had not participated in sports (S. Kwon et al. 2015). Yet, this may be partially due to the major contributing factors of drop-out including lack of enjoyment, competing interests, and injuries (Crane and Temple 2015). A longitudinal Finnish study has shown educational differences in the effects of competitive sports participation and exercise in adolescence on adulthood LTPA. Mäkinen et al. (2010) have found that among the low-educated participation in competitive sports directly associated with adult LTPA, whereas among the high-educated, exercise in late adolescence directly associated with adult LTPA. The socioeconomic differences in physical activity patterns are well-known, and LTPA levels in adulthood tend to be higher among those with higher socioeconomic position (Bauman et al. 2012).

Several major life events which have an impact on physical activity might take place in the transition to adulthood and may occur differently between socioeconomic groups. The transition to university, having a child, and experiencing multiple simultaneous life events have been shown to reduce LTPA among both sexes (Condello et al. 2017; Engberg et al. 2012). Based on age-specific evidence among females, entering working life, a change in work conditions, changing from being single to cohabitation, getting married, pregnancy, divorce/separation and reduced income tend to reduce physical activity, whereas starting a new personal relationship, returning to study and harassment at work tend to increase physical activity (Engberg et al. 2012). During the time- and energy-consuming life events, the association of LTPA with self-efficacy and motivation becomes evident (Bauman et al. 2012). Intrinsic motivation, including enjoyment and mastery, is positively associated with LTPA both cross-sectionally in adulthood and longitudinally from adolescence to adulthood (Aaltonen et al. 2013; Engström 2008). In the longitudinal Finnish study, only a few adults participated in the same sports in which they had competed in earlier in life, yet they maintained high levels of LTPA in adulthood (Mäkinen et al. 2010). Thus, high LTPA levels in adulthood seem not to be dependent on continued competitive sport participation but is associated with sport activity experiences, including competition, in adolescence (Cleland et al. 2012; Engström 2008; Jose et al. 2011; Kjonniksen et al. 2008).

In conclusion, accumulated evidence indicates that participation in a diversity of sport activities in adolescence may be beneficial in the aim to maintain LTPA levels in the transition to adulthood. Table 2 summarizes the prospective population-based studies which have addressed the association between the diversity of sport activities and physical activity level later in life. However, scant longitudinal data are available on the associations between the quantity and quality of sport activities in adolescence and LTPA in adulthood. Furthermore, to my knowledge, none of the previous studies have used a twin study design, which enables adjusting for potential confounding by familial factors including genes and family environment.

2.3 SPINAL PAIN

The term “spinal pain” is used to describe pain at the different levels of the spinal column (cervical, thoracic, lumbar and sacral) , including neck pain and low back pain (LBP)(Dionne et al. 2008). Pain is generally described as “an unpleasant sensory and emotional experience” and is a subjective experience (IASP Task Force for Taxonomy 2004). Most studies in the field have examined LBP or neck pain, whereas thoracic pain has been less studied (Briggs et al. 2009). In some studies, spinal pain refers to low back and neck pain (Lheureux and Berquin 2019), whereas in some studies, neck, thoracic and low back pain are considered (Hartvigsen et al. 2009; Leboeuf-Yde et al. 2012; Leboeuf-Yde et al. 2009).

Since pain is a subjective experience, the assessment is typically based on self-reports, describing the frequency, intensity, duration of the pain and associated disability. The intensity of pain is often assessed with scales such as the Visual Analogue Scale (VAS), Verbal Rating Scale (VRS), and Numeric Rating Scale (NRS) (Williamson and Hoggart 2005). Even though the intensity of the pain may be the most salient dimension, it is not the only important one and is influenced by the patient's perception of the pain and its expected duration (Turk and Melzack 1992). Psychological factors play an evident role in the experience of pain which may lead to altered behavior, dysfunction or even disability. Evidence demonstrates that pathology and pain have a poor correlation, which means that even in the absence of a pathological process, pain may be present (Turk and Melzack 1992; Williamson and Hoggart 2005). This knowledge is crucial considering the high prevalance of spinal pain that is associated with disability in all age groups.

Globally, low back and neck pain are the most common musculoskeletal problems and leading causes of disability (Vos et al. 2016). The lifetime prevalence estimates for LBP range from 39% up to 84% (Airaksinen et al. 2006; Hoy et al. 2012). Even though neck pain is not as common as LBP, about two-thirds of people experience neck pain during their lifetime (Fejer et al. 2006a; Haldeman et al. 2010). Fewer estimates are available on thoracic pain which, however, is also a common problem in the general population, with lifetime prevalence ranging from 12 to 31% (Briggs et al. 2009). Consistent with the global estimates, in a large Danish population-based twin sample, the prevalence estimates of pain for at least 30 days were highest for LBP (12%), followed by neck (10%) and thoracic (4%) pain (Leboeuf-Yde et al. 2009). Spinal pain at all levels is more often reported by females than males, but low back and neck pain seem to peak during middle age (Hogg-Johnson et al. 2008; Hoy et al. 2012), whereas thoracic pain seems to be most common among children and adolescents (Briggs et al. 2009). This thesis focuses on the two most dominant spinal pain problems, i.e., pain in the low back and neck. The latter, however, is dealt with as a broader concept , i.e., neck–shoulder region pain (NSP) including pain areas lateral to the spinal column also.

2.3.1 LOW BACK PAIN

LBP is a common symptom rather than a specific disease (J. Hartvigsen et al. 2018). Thus, LBP is defined by the area of pain, typically between the lowest ribs and gluteal folds (Dionne et al. 2008). Several pathologies can cause LBP, however, in most cases no specific nociceptive cause can be detected (J. Hartvigsen et al. 2018). Hence, the majority of LBP is non-specific but has a favorable prognosis, and pain levels tend to decline within a few weeks (Maher et al. 2017; Menezes Costa et al. 2012). The duration of LBP is often categorized into acute, subacute, and chronic, but consistent criteria for these categories are lacking (J. Hartvigsen et al., 2018; Konstantinou and Dunn, 2008). In review studies, chronic or persistent LBP is usually defined to last at least 3 months (J. Hartvigsen et al. 2018). In the Finnish Current Care Summary, acute LBP is defined to last less than 6 weeks, subacute LBP is from 6 to 12 weeks, and chronic LBP continues more than 12 weeks ("Low Back Pain: Current Care Guidelines" 2017). The classification follows the common perception that acute LBP tends to completely resolve in 4–6 weeks, whereas persistent LBP has a worse prognosis and is unlikely to recover completely (Maher et al. 2017).

Acute LBP may be caused by physical (e.g., awkward working positions) or psychosocial factors (e.g., being fatigued or tired), or a combination, but in about every third case the patient cannot identify a trigger (Maher et al. 2017). Persistent LBP may rarely be caused by a severe condition such as malignancy, vertebral fracture, infection, or inflammatory disorder such as axial spondyloarthritis, which are screened for by interviewing the patient for specific symptoms and medical conditions such as previous cancers, traumas, fever and night pain (J. Hartvigsen et al. 2018; "Low Back Pain: Current Care Guidelines" 2017; Maher et al. 2017). Commonly, LBP can also present itself with pain in one or both legs and sometimes with neurological symptoms in the lower limbs (J. Hartvigsen et al. 2018; Konstantinou and Dunn 2008). LBP with related leg pain is known by several terms including sciatica, lumbosacral radicular syndrome, radiculopathy, and nerve root pain. Though the most commonly used, sciatica is considered a controversial term and the more descriptive terms of radiculopathy and nerve root pain are preferred when leg pain is caused by lumbosacral nerve root involvement (Konstantinou and Dunn 2008). Of importance is both clinical and epidemiological evidence suggesting that LBP with related leg pain has a poorer prognosis compared to LBP without leg pain (L. Hartvigsen et al. 2017; Kongsted et al. 2012; Konstantinou and Dunn 2008). Subsequently, primary care LBP researchers have set the identification of both prevention and treatment strategies for different types of LBP as their top priority (Stynes et al. 2016). In regards to the above literature, this thesis uses the term LBP to describe non-specific low back pain and the terms radiating (LBP with related leg pain) and non-radiating LBP (LBP without leg pain) to discriminate between the two different LBP types without any clinical evidence on nerve root involvement.

The assessment of LBP can be based on self-reporting with questionnaires or interviews, as well as more objective clinical assessment. Over the years, a range of questionnaires have been created for pain prevalence estimations, assessment of disability in chronic LBP patients, and as prognostic screening instruments to screen for poor outcomes among LBP patients (Dionne et al. 2008; Karran et al. 2017; Roland and Fairbank 2000). In the scope of this thesis, only the most commonly used LBP questionnaires are mentioned here. Through a consensus approach, 28 back pain experts from 12 countries agreed on a minimal definition for LBP prevalence to include two questions: "In the past 4 weeks have you had pain in your low back (in the area shown in the diagram)?" with a diagram showing the area of interest and "If yes, was this pain bad enough to limit your usual activities or change your daily routine for more than 1 day?” (Dionne et al. 2008). The optimal definition also includes questions considering radiating LBP “Have you had pain that goes down the leg?”, “If yes, has this pain spread below the knee?”, a request not to report pain related to feverish colds or menstruation, frequency of pain during the past 4 weeks, the duration of pain, and a numeric rating scale from 0 (no pain) to 10 (the worst pain imaginable) for the severity of pain during the past 4 weeks (Dionne et al. 2008). With these questions, different kinds of LBP categories can be created and prevalences estimated. Overall, self-reported musculoskeletal diseases and problems have been found to have a fair to good test–retest reliability, which depends on question wording and recall period (Gill et al. 2016; Picavet and Hazes 2003).

For decades already, the two most frequenctly used and recommended questionnaires in the assessment of disability related to LBP have been the Roland-Morris Disability Questionnaire (RMDQ) and the Oswestry Disability Index (ODI) (Chiarotto et al. 2016; Roland and Fairbank 2000). A meta-analysis of the developer-recommended versions of the questionnaires, i.e., original 24-item RMDQ and ODI 2.1a, found no strong reasons for favoring one of them, yet all studies included were considered to have poor or fair methodological quality (Chiarotto et al. 2016). More recently developed prognostic screening instruments for primary care use assess certain factors related to an individual’s pain experience (including pain intensity and functional impairment) and certain psychosocial factors which are known to be associated with chronic LBP (Karran et al. 2017). Two frequently used instruments, validated in several counties and languages, are the Örebro Musculoskeletal Pain Screening Questionnaire (OMPSQ) and the STarT Back Screening Tool (SBST) (Lheureux and Berquin 2019). The use of screening instruments has been recommended to guide the management of LBP, but in primary care they seem to rather poorly (probability 60-70%) discriminate between individuals who develop chronic pain and those who do not (Karran et al. 2017). In the prediction of persistent disability (70–80% probability of correct classification) and return to work (>80% probability), the screening instruments seem to perform better, but due to their original purpose some of them are better at predicting the return to work (OMPSQ) and others in disability outcomes (SBST) (Karran et al. 2017; Lheureux and Berquin 2019). Regarding radiating LBP, the Quebec Task Force (QTF) on Spinal Disorders has created a diagnostic classification with 11 categories primarily for clinicians, and the categories 1–4 (LBP alone, LBP + leg pain above the knee, LBP + leg pain below the knee, LBP + signs of nerve root involvement) have been found to be helpful in the identification of different LBP subgroups with differing outcomes in clinical settings (L. Hartvigsen et al. 2017; W. Spitzer 1987).

LBP is currently the leading cause of disability, globally burdening both the individuals with reduced quality of life and the societies with large costs due to increases in the utilization of healthcare services and to lost workdays

(Holtermann et al. 2010; Manchikanti et al. 2009; Vos et al. 2016). The one-year prevalence for LBP is around 38%, whereas the lifetime prevalence estimates range from 39% up to 84% (Airaksinen et al. 2006; Hoy et al. 2012). Radiating LBP is less common than non-radiating LBP, with estimated point prevalences in adult populations ranging from 1.6 to 13.4% and from 1.0 to 49.7% (mean 18.3%), respectively (Hoy et al. 2012; Konstantinou and Dunn 2008). In a sample of young Finnish adults, the annual incidence of moderate LBP (8–30 days duration) has been found to be 13.2% and the incidence of radiating LBP to be 8.6% (Shiri et al. 2010a). Globally, LBP is extremely common in all age groups, whereas the prevalence of radiating LBP increases more with age (J. Hartvigsen et al. 2018; Konstantinou and Dunn 2008).

Further, LBP is more commonly reported by females than males (Hoy et al. 2012). In the national FinHealth study in 2017, back pain during the past 30 days was most common among males aged 40–49 (50.2%) and among females aged 80+ (56.0%) (Koponen et al. 2018). The LBP prevalence among all males over age 30 was 44.4% and 48.1% among females. Thus, in comparison, the prevalences are surprisingly high in the 30–39-years-old age group: 49.5% in males and 50.7% in females (Koponen et al. 2018). Although partly explained by the change in questionnaire items, there was a distinct decrease in back pain prevalence in Finland among both sexes and in all age groups, especially within the oldest, between 2011 (the Health 2011 survey) (Koskinen et al. 2012) and 2017 (the FinHealth study) (Koponen et al. 2018). Yet, back pain is still a very common health problem causing large societal costs. Based on Finnish statistics between 1995–2005, the cost of back pain care was around 35 million euros annually and the costs of disability pensions were around 329.4 million euros (Pohjolainen et al. 2017). Even though most individuals with LBP have low levels of disability, it is concerning that the disability caused by LBP seems to be highest among working age groups (J. Hartvigsen et al. 2018). In Europe, the most common reason for medically certified sick leave and disability pension is LBP (Bevan et al. 2009).

Both non-specific and radiating LBP are multifactorial problems related to individual characteristics and physical stress on the spine. LBP episodes tend to be recurrent and thus, previous pain is a common risk factor for LBP (Taylor et al. 2014). Other well-known risk factors for LBP are poor general health, obesity and smoking, as well as psychological stress and sleep problems (Parreira et al. 2018). Both self-assessed poor health and co-morbidities such as osteoarthritis have been associated with LBP (Ferreira et al. 2013). A meta-analysis on LBP has indicated that in comparison to non-overweight people, overweight people have a higher risk for LBP and obese people an even higher risk than overweight people (Shiri et al. 2010b). Based on a meta-analysis on sciatica and BMI, there is even a dose–response relationship and both overweight and obesity are risk factors for radiating LBP (Shiri et al. 2014). In another meta-analysis, compared to never smokers, former smokers had more LBP and current smokers even more (Shiri et al. 2010c). A Finnish study including four prospective cohort studies (N=34,589) found that both current smoking and obesity (defined by both BMI and waist circumference) increase the risk of hospitalization for sciatica (Shiri et al. 2017). In contrast, a previous Finnish study (N=1224) found no association between BMI and the incidence of radiating or non-radiating LBP, whereas waist circumference, i.e., abdominal obesity, had a positive association with the incidence of radiating LBP (Shiri et al. 2013). However, the differing results may also reflect the distinct outcomes, since the meta-analysis already indicated that overweight and obesity have the strongest associations with seeking care for LBP and chronic LBP (Shiri et al. 2010b). Consistently, reviewed evidence on longitudinal twin studies indicates an association between smoking, obesity, lower socioeconomic levels, and depression with only longer lasting LBP (e.g., 30 days during the past year) (Ferreira et al. 2013). The role of socioeconomic status in LBP prevalence is, however, somewhat ambiguous and probably mediated through occupational physical activity. Higher education has been found to be associated with a lower risk of chronic disabling LBP (Chou and Shekelle 2010), but higher socioeconomic status seems not to protect from LBP, whereas physical workload is more clearly associated with LBP (Ferreira et al. 2013; Parreira et al. 2018). A study of European Working Conditions found large differences in back pain prevalence between countries and occupational groups (Farioli et al. 2014). The detected differences between occupational groups were, however, largely explained by personal risk factors including occupational demands, whereas the differences between countries seemed to be partly attributable to socioeconomic differences.

The role of physical stress on the spine, including occupational demands and activities in leisure-time, seems to be one of the most complicated. Whereas regular LTPA may even protect against chronic LBP, many occupational physical activities may actually be harmful (Heneweer et al. 2011; Shiri and Falah-Hassani 2017). The role of LTPA will be further elucidated in section 2.3.1 and thus, only the role of occupational physical activity is briefly described in this section. Higher physical workload has consistently been associated with LBP (Ferreira et al. 2013; J. Hartvigsen et al. 2018). Several occupational exposures such as whole-body vibration, (heavy) lifting, working in awkward postures such as kneeling or bending, and prolonged driving, standing and walking are related to increased risk of LBP (Coenen et al. 2014; Taylor et al. 2014). Nevertheless, a previous summary of eight systematic reviews concluded that the evidence on causality regarding these exposures and incidence of LBP is conflicting or non-existent (B. K. Kwon et al. 2011). However, as discussed in the summary, the insufficient or poor quality of the reviewed studies, as well as the difficulty to define the cause of LBP may explain the lack of causality. Moreover, the lack of evidence on causality does not affect the possibility that individuals may consider specific occupational physical activities to cause their LBP (B. K. Kwon et al. 2011). A recent Finnish study also found that exposure to heavy physical work from early to later adulthood was associated with primary healthcare visits in midlife due to three different reasons: any musculoskeletal disease, spine disorders, and upper extremity disorders (Halonen et al. 2019). Another study from the same sample has indicated that high physical workload in young adulthood may be a long-lasting risk factor for LBP, especially for radiating LBP (Lallukka et al. 2017). This is concerning regarding the often experienced recurrent nature of LBP (Axén and Leboeuf-Yde 2013). In addition to active work, high job strain and sleep disturbances have been identified as prognostic factors for troublesome LBP (Rasmussen-Barr et al. 2017).

Thus, not only physical stress but also psychological stress and factors have been related to the etiology of acute pain, the transition to chronic pain, and increased risk of chronic disabling LBP (J. Hartvigsen et al. 2018; Parreira et al. 2018). The frequently studied psychological factors including depression, anxiety, catastrophizing, and self-efficacy are often considered separately, yet tend to have a substantial overlap (J. Hartvigsen et al. 2018). Catastrophizing means “an irrational belief that something is far worse than it really is”, whereas self-efficacy is “belief in one’s ability to influence events affecting one’s life”. The fear-avoidance model of chronic pain that was originally formulated for back pain in 1995 by Vlayen et al. (Vlaeyen et al. 1995) describes how the experience of acute pain may lead to a vicious circle of chronic disability and suffering (Crombez et al. 2012). Patients’ interpretation of pain is at the core of the model. Common misinterpretations are that pain is caused by tissue damage which will lead to disability and that pain can only be treated medically. This catastrophizing feeds the irrational fear of injury and movement, “kinesiophobia”, and thus, avoidance of movement.

Interestingly, pain cognitions seem to have an even greater influence than the pain itself on the development and maintenance of disability (Crombez et al. 2012; Linton 2000). Reviewed evidence on central pain processing and modulation shows that patients with chronic LBP have structural brain differences in specific cortical and subcortical regions, as well as differing functional connectivity in pain-related regions after painful stimulus (Kregel et al. 2015). Even though the clinical significance of the structural and functional brain abnormalities remains uncertain, these findings provide support for the biopsychosocial model of pain and further highlight the role of cognitive factors in the development of pain and disability (Linton 2000). According to a review of prospective studies, the most useful predictors of persistent disabling LBP were maladaptive pain coping behaviors, nonorganic signs, functional impairment, general health status, and presence of psychiatric co-morbidities (Chou and Shekelle 2010). Similarly, reviewed evidence on prognostic factors for work participation among patients with sciatica identified that better pain coping, less depression and mental stress, as well as less fear of movement are favorable factors for returning to work (Oosterhuis et al. 2019). Overall, it is noteworthy that psychosocial factors generally have a greater impact on back pain disability compared to biomedical or biomechanical factors (Linton 2000).

One more important role in the development and prevalence of LBP is played by genetics. Twin studies have reported that heritability estimates for

LBP range from 21% to 67% (Ferreira et al. 2013). Heritability estimates report the variation in a trait due to genetic differences between individuals in a given population at a given time. In the case of LBP, the contribution of genetic factors seems to be greater in more severe conditions (Ferreira et al. 2013). However, no specific genes have been identified. Regarding the above described psychological factors, some recent twin studies have suggested that there is a genetic link between depression, sleep quality, and pain (Fernandez et al. 2017; Gasperi et al. 2017). Thus, genetics may play a crucial part particularly in the transition from acute to chronic LBP.

Given the high prevalence and the recurrent and disabling nature of LBP that leads to huge individual and societal burdens, prevention is more than necessary. Cost-effective and context-specific strategies are required for the management of different types of LBP to ease both the current and future burden (J. Hartvigsen et al. 2018).

2.3.2 NECK–SHOULDER REGION PAIN

Similar to LBP, neck pain is also considered as more a symptom than a specific disease. The Neck Pain Task Force has defined the anatomical region of neck pain as follows: below the superior nuchal line/external occipital tuberans and inferior mandibular borders and above the spines of scapulas, superior clavicle borders and suprasternal notch (Guzman et al. 2008). Additionally, they stated on page S18 that “neck pain may be a feature of virtually every disorder and disease that occurs above the shoulder blades” including rare, severe causes of neck pain such as deep infections (Bliss, Flanders, and Saint 2004), tumors, and traumatic injuries (Sterling et al. 2019). Neck pain may also be related to headaches, temporomandibular joint syndrome, disturbances of vision, certain types of stroke, disorders affecting the upper extremities, inflammatory arthropathies, and fibromyalgia (Harris et al. 2006). Yet, the common neck pain tends to be non-specific and, also referred to as “soft tissue” or “mechanical neck pain” (Guzman et al. 2008). In the Finnish Current Care Guidelines, the neck pain is considered to be acute if the duration is less than 12 weeks and chronic if the duration is more than 12 weeks (“Neck Pain: Current Care Guidelines” 2017), whereas a Swedish study classified neck pain lasting over 30 days as subacute or chronic neck pain (Pico-Espinosa et al. 2019). Thus, similar to LBP, a consensus on classification based on neck pain duration is lacking. Furthermore, pain in the neck–shoulder region is rather difficult to localize precisely and often affects both the neck and shoulders, which has led several studies to consider it as a single diagnostic entity (Sarquis et al. 2016). In this thesis, the term neck–shoulder region pain, i.e., NSP, is used to describe non-specific pain in the neck and/or shoulder.

NSP can be assessed with self-reports including questionnaires or interviews, as well as with more objective clinical assessment. The Neck Pain Task Force has suggested a 5-axis system to classify published studies and to improve the full case definitions in new studies as follows: 1) the source of subjects and data, 2) the setting or sampling frame, 3) the severity of neck pain and its consequences, 4) the duration of neck pain, and 5) its pattern over time (Guzman et al. 2008). The source of subjects and data can be divided into neck pain in surveys (non-interfering or interfering), consultation for neck pain, and neck pain compensation claim, the latter two being interfering and thus, somewhat more objectively defined. This thesis focuses on the NSP in surveys, where the setting or sampling frame can be the general population, employed populations, specific occupations, or injury surveillance in sporting events.

The severity of NSP may be classified by a system proposed by von Korff et al. (1992) as follows: grade I low intensity–low disability, grade II high intensity–low disability, grade III high disability and moderately limiting, and grade IV high disability and severely limiting. In addition, the Quebec Task Force has created a specific classification for the Whiplash Associated Disorder (neck pain which occurs after a traffic collision) ranging from 0 ("no complaint about the neck, no physical sign") to 4 ("neck fracture or dislocation") (Spitzer et al. 1995). The Neck Pain Task Force has proposed that the duration of NSP could be categorized as follows: 1) transitory neck pain which lasted less than 7 days; 2) short-duration neck pain that lasted 7 days or more, but less than 3 months; 3) long-duration neck pain that lasted 3 months or more, which is in line with the Finnish Guidelines (Guzman et al. 2008; "Neck Pain: Current Care Guidelines" 2017). The proposed patterns of pain are a single episode with no previous NSP and full recovery afterwards, recurrent NSP with 2 or more episodes and full recovery in-between, and persistent pain without periods of full recovery (Guzman et al. 2008). Recently, a large, longitudinal study including over 12,000 workers from 18 countries concluded that NSP mostly occurs together with current or recent pain in some other part of the body, and this generalized pain is more troublesome and disabling compared to pain only in the neck–shoulder region (Sarquis et al. 2016). Thus, in addition to the 5-axis system, the Neck Pain Task Force suggested that a sixth dimension considering pain in other anatomical regions would probably be useful in NSP studies.

Several self-reported outcome measures for non-specific neck pain have been validated and used in survey studies. A systematic review on disease-specific questionnaires in patients with neck pain identified 8 different questionnaires which have been developed to measure pain and/or disability (Schellingerhout et al. 2012). The most commonly used and evaluated questionnaire was the Neck Disability Index which is derived from the Oswestry LBP Disability Index (Roland and Fairbank 2000; Vernon and Mior 1991) and seemed to have good internal consistency, content validity, structural validity, hypothesis testing, and responsiveness. However, limited evidence showed its inadequate reliability. The evidence on other questionnaires displayed positive results but was considerably limited. An Italian review assessed five instruments (Neck Disability Index, Neck Pain and Disability Scale, Neck Bournemouth Questionnaire, Core Outcome Measures

Index, and NeckPix©) that have been validated in the Italian language and found psychometric weaknesses or problems in all of them, thus none was considered to be a gold standard method (Pellicciari et al. 2016). However, Pelliciari et al. concluded that the Neck Bournemouth Questionnaire may have the best psychometric validity. The conclusions of Schellingerhout et al. (2012) were that rather than developing new neck pain questionnaires, the current ones should be adequately assessed.

Along with LBP, NSP is globally considered to be a leading cause of disability (Vos et al. 2016). Even though NSP is not as common as LBP, about two-thirds of people experience NSP during their lifetime (Fejer et al. 2006a; Haldeman et al. 2010). One-year prevalence in the general and working populations ranges from 30% to 50%, and also among children and adolescents from 20% to 40% (Haldeman et al. 2010). NSP seems to increase with age and the peak prevalence occurs during middle age (Hogg-Johnson et al. 2008). Some evidence, however, suggests that adult chronic neck pain already has its origin in childhood or adolescence (El-Metwally et al. 2004; Siivola et al. 2004). In the FinHealth study in 2017, neck pain during the past 30 days was most common among males aged 40–49 (39.3%) and among females aged 30–39 (59.1%). The prevalence of neck pain among participants aged 30 years or older was 36.6% in males and 50.5% in females. In the FinHealth study in 2017, shoulder pain was categorized as its own entity and the prevalence among participants aged 30 years or older was 37.0% in males and 39.1% in females (Koponen et al. 2018). Thus, consistent with the global evidence, females report more often NSP than males (Haldeman et al. 2012). Similar to LBP, NSP also creates burden in individuals, as well as large costs for societies both through increased healthcare expenses and lost workdays (Holtermann et al. 2010; Manchikanti et al. 2009).

The multifactorial nature of NSP is well-known and also considers the prognosis. Previous neck pain episodes have been connected to poorer prognosis of the current episode among workers and the general population (Haldeman et al. 2010; Palmlof et al. 2016). The estimates suggest that most individuals with neck pain do not fully recover, since 50–85% of those who have had initial neck pain will experience it again within 1–5 years (Carroll et al. 2008). A more recent trajectory study, however, detected that most individuals who experienced disabling neck pain over 30 days had a decrease in pain intensity within a year, whereas a quarter had an unfavorable trajectory (Pico-Espinosa et al. 2019). Unfavorable trajectories were related to factors such as sudden onset of pain, high pain intensity at baseline, depressive symptoms, younger age, and female sex. Additionally, the prognosis for Whiplash Associated Disorder seems to be worse than for non-traumatic neck pain (Sterling et al. 2019). In the general population, poor general and psychologic health, as well as smoking, have been related to increased risk of neck pain (Hogg-Johnson et al. 2008). Poor self-assessed health, healthcare visits for various reasons and previous LBP are independent risk factors for neck pain, whereas BMI seems not to be (Croft et al. 2003; Croft et al. 2001).

Current smokers compared to never smokers have been reported to have an increased risk for cervical disc herniation and more self-reported neck pain (Hogg-Johnson et al. 2008). The majority of evidence suggests no association between socioeconomic status or its correlates (e.g., education or income) and neck pain (Hogg-Johnson et al., 2008). A study found a link between employment status and neck pain only among those who were not working due to ill health and/or disability and had a higher incidence of neck pain (Croft et al. 2001).

The evidence on the associations of work activity and LTPA with NSP is ambiguous. Physical demands at work including repetitive and precision work, sedentary work position, working constantly with neck in flexion, lifting, chairs without armrests, poor position of keyboard, mouse, or computer monitor have been identified to increase the risk for neck pain (Haldeman, et al. 2010; Sarquis et al. 2016). In addition, psychological factors such as high psychological job strain, low social support among coworkers and job insecurity seem to increase the risk for neck pain (Haldeman et al. 2010).

Thus far, convincing evidence on successful workplace interventions to reduce NSP among workers with improving workstations and worker posture are lacking. Accordingly, specific workplace or physical job demands are not related to recovery from neck pain among workers, whereas participation in general exercise and sport activities has been related to more likely improvement in neck pain among workers (Haldeman et al. 2010). A large Swedish cohort study, however, found that physical activity reduced only the risk for neck pain among those who had no previous history of neck pain (Palmlof et al. 2016). Using the same Stockholm Public Health Cohort, Skillgate et al. (2017) found that healthy lifestyle behavior (including physical activity, alcohol intake, smoking, and diet) seemed to protect from prolonged troublesome neck pain among females. The association between LTPA and NSP will be further described in section 2.4.2.

Psychological factors have also been related to onset of NSP, recovery and the possible transition to chronic NSP. Particularly, emotional, cognitive and behavioral factors are significant in both NSP and LBP, but personality factors have shown ambiguous results (Linton 2000). Poor psychological health, worrying, and becoming angry or frustrated due to neck pain have been linked to unfavorable prognosis, whereas greater optimism, self-assuring and less social coping styles have been related to favorable prognosis in general populations (Haldeman et al. 2010). The fear-avoidance model that was described in section 2.1.4. also applies to NSP since the experienced pain may reduce physical activity due to perceived disability and catastrophizing behavior (Crombez et al. 2012). Furthermore, a longitudinal Finnish study found that psychosomatic symptoms in adolescence may predict newly reported NSP in young adulthood (Siivola et al. 2004). Additionally, the recent trajectory study linked depressive symptoms to unfavorable neck pain tracjetories among adults (Pico-Espinosa et al. 2019). Thus, both past and current psychological factors may play a role in NSP incidence and prevalence, as well as in NSP-related disability.

Twin studies have estimated heritability rates for NSP similar to LBP, around 35% (Nielsen et al. 2012). The estimates for neck pain have ranged from 24% to 58%, and the largest study by Fejer et al. (2006b) found significantly higher heritability in males (52%) compared to females (34%), as well as decreasing heritability with increasing age (Nielsen et al. 2012). The age-related decrease in heritability estimates suggests that the role of unique environmental influences increases during adulthood. This is promising in the sense that through environmental changes it may be possible to reduce the risk and incidence of NSP. Considering the remarkable individual and societal burden caused by NSP, preventive actions are more than warranted.

2.4 LEISURE-TIME PHYSICAL ACTIVITY AND SPINAL PAIN

The association between LTPA and spinal pain is still uncertain and ambiguous since physical stress on the spine may be both beneficial and harmful. When compared to inactivity, participation in LTPA has demonstrated slightly favorable associations with both LBP and NSP in survey studies among adult populations (Landmark et al. 2013; Palmlof et al. 2016; Shiri and Falah-Hassani 2017). However, some evidence has suggested that participation in vigorous activities is associated with unfavorable outcomes (Heneweer et al. 2011; Villavicencio et al. 2007). One study suggested that despite the higher risk of injuries, adolescent athletes may have less spinal symptoms compared to non-athlete peers (Legault et al. 2015), whereas another study among adolescents found a positive dose-response relationship between organized sport participation and spinal pain (Kamada et al. 2016). Concerning is that spinal pain causes remarkable disability already among adolescents, and in up to every fourth case, school or physical activities are affected (Kamper et al. 2016). Moreover, people with recent spinal pain have been shown to be less likely to reach the physical activity recommendations (Zadro et al. 2017). Yet, intervention studies have indicated that different types of exercise are effective in the treatment of spinal pain by reducing pain prevalences, reducing pain levels, maintaining fitness, and improving back-related function (Jensen and Harms-Ringdahl 2007; Ribaud et al. 2013; Shiri et al. 2018; Sterling et al. 2019; Wieland et al. 2017; Yamato et al. 2016). The Finnish Current Care guidelines also suggest physical activity as a first-line treatment for LBP and NSP ("Low Back Pain: Current Care Guidelines" 2017; "Neck Pain: Current Care Guidelines" 2017). Thus, spinal pain may be treated with certain types of exercises, yet the type and dose of LTPA that could prevent spinal pain has remained debatable.

Reviewed population-level evidence shows that the association between LTPA and LBP has been widely studied compared to that of LTPA and NSP (Sitthipornvorakul et al. 2011). Furthermore, even though all spinal problems share similar characteristics, LBP seems to more often lead to some kind of consequences such as care-seeking behavior, reduced physical activities, sick-leave, and disability pension in general populations (Leboeuf-Yde et al. 2012). Among athletes, LBP and NSP have been associated with somewhat different risk sports (Farahbakhsh et al. 2018; Noormohammadpour et al. 2018; Trompeter et al. 2017). In the words of Kujala et al. “The type and location of musculoskeletal pain are specific to each type of activity” (Kujala et al. 1999). Thus, regarding the varying quality and quantity of evidence, this thesis examines the association of LTPA with LBP and NSP separately.

2.4.1 LOW BACK PAIN

Previous studies on the association between LTPA and LBP in adult populations have concentrated on the dose rather than the diversity of LTPA. Meta-analyses have indicated that LTPA may modestly reduce the risk of radiating LBP (Shiri et al. 2016) and chronic non-specific LBP (Shiri and Falah-Hassani 2017). By being moderately or highly active (i.e., participating in LTPA at least 1–3 hours per week), the risk of chronic non-specific LBP could be lowered by 11–16%. The risk of LBP during the past month or past 6–12 months, however, had no association with LTPA in the meta-analysis of 36 prospective cohort studies (Shiri and Falah-Hassani 2017). The meta-analysis of cohort studies on LTPA and radiating LBP found that high levels of LTPA (i.e., more than 4 times per week) were inversely associated with the onset of radiating LBP. In contrast, the meta-analysis of cross-sectional studies detected that participation in LTPA at least once per week was associated with a higher risk of LBP (Shiri et al. 2016). Some previous evidence has also suggested that the relationship between physical activity and LBP is a U-shaped curve, meaning that both physical inactivity and a high level of physical activity may increase the risk of both radiating (Shiri et al. 2013) and non-radiating LBP (Schiltenwolf and Schneider 2009), particulary in females (Heneweer et al. 2011). The most recent meta-analysis, which included 15 cohort and 9 cross-sectional studies, considered only the initial episodes of non-specific LBP and found an inverse association between LTPA and LBP but no evidence of a dose-response (Alzahrani et al. 2019). For the first time, Alzahrani et al. (2019) calculated LTPA as MET-hours/week and reported a similar reduction in the risk of LBP with medium and high levels of LTPA as Shiri et al. (2017). In conclusion, regular participation in some LTPA compared to inactivity seems beneficial in terms of LBP in the long-term, yet participation in high level or intensity LTPA may increase the risk of subsequent LBP.

Several studies have examined the associations between specific sport activities and LBP, although mostly in adolescent and athlete populations. Some evidence indicates that LBP is more common among adolescents who participate in organized sports, especially in competitive sports, compared to non-participants (Balagué et al. 1999; Kamada et al. 2016; Rossi et al. 2016). However, a large Canadian study has shown that adolescent athletes have less LBP compared to non-athlete peers (Legault et al. 2015). Among current and former adult athletes, LBP seems to not be more common than among other physically active individuals (Fett et al. 2019; Foss et al. 2012; Videman et al. 1995). In population-based adolescent samples, participation in extreme, strength, aesthetic, and technical sports such as rock climbing, gym training, gymnastics, and downhill skiing have been related to a higher risk of LBP (Auvinen et al. 2008; Guddal et al. 2017; Sato et al. 2011). Similarly, among adult athletes, LBP prevalence is high among gymnasts, dancers, and figure skaters (Fett et al. 2017; Triki et al. 2015). In contrast, despite an association between maximal weight lifting and greater lumbar degeneration, former weight lifters have reported less LBP compared to adult control subjects (Videman et al. 1995). In many team sports, such as volleyball, floorball, basketball, and ice hockey, LBP is a common complaint among both adolescent and adult athletes (Farahbakhsh et al. 2018; Jonasson et al. 2011; Noormohammadpour et al. 2018; Purcell and Micheli 2009; Sato et al. 2011; Triki et al. 2015). In addition, among young adult athletes, participation in combat sports, such as karate and judo, has been related to a higher risk of LBP (Daniels et al. 2011; Kamada et al. 2016; Noormohammadpour et al. 2016; Triki et al. 2015). In contrast, endurance sports have been related to less LBP among adolescents and adult athletes. In a cross-sectional Norwegian study, girls who participated in endurance sports reported less LBP, and in a cross-sectional Finnish study both boys and girls who participated in cross-country skiing had less LBP (Auvinen et al. 2008; Guddal et al. 2017). Adult athletes, triathletes, runners, and orienteerers have been shown to have a lower prevalence of LBP, whereas among cross-country skiers and rowers the prevalences have been higher (Farahbakhsh et al. 2018; Fett et al. 2017; Foss et al. 2012; Trompeter et al. 2017; Videman et al. 1995). An American survey of triathletes reported lifetime prevalence of 67.8% for LBP and 28.7% (25 out of 87 respondents) for sciatica (Villavicencio et al. 2006). A study among recreational cyclers detected that those who cycled 160 km or more per week experienced LBP 3.6 times more likely compared to those who cycled less than 160 km per week (Schultz and Gordon 2010). In summary, the associations between specific sport activities and LBP are somewhat different for adolescents and adult athletes.

Notably, adolescent, athlete, and adult populations have considerable differences in the causes of LBP. In adolescent athletes, trauma, spondylolysis/spondylisthesis and hyperlordosis are common causes of LBP, whereas in adult populations the primary causes are mechanics and osteoarthritis (Daniels et al. 2011). This is in line with the evidence that activities with a high risk of trauma, such as combat sports and gymnastics, or activities with heavy forces, such as gym training and downhill skiing, are associated with LBP in adolescence and among young adult athletes (Auvinen et al. 2008; Balagué et al. 1999; Guddal et al. 2017; Noormohammadpour et al. 2016; Triki et al. 2015). Additionally, repetitive extension, flexion, and rotation, as well as participation in overhead activities, have different effects on adolescent and adult athletes. Among young athletes, sports involving repetitive (hyper)extension, flexion, and rotation, such as gymnastics and volleyball, have been associated with a higher risk of LBP (Daniels et al. 2011; Purcell and Micheli 2009). However, adult athletes who participate in repetitive overhead activities, such as volleyball and tennis, or former endurance athletes with a history of prolonged and repetitive flexion and extension (cross-country skiers, rowers, and orienteerers) have reported no more LBP compared to physically active controls (Fett et al. 2019; Foss et al. 2012). Evidently, the difference between current and former athletes may be partially explained by the training-related soreness. Overall, among athlete populations the risk of LBP has been related to sport type, repetitive loads, and training load, as well as previous LBP episodes (Daniels et al. 2011; Moradi et al. 2015; Villavicencio et al. 2006).

Especially worrysome is that many adolescents who participate in sports have reported overuse as the origin of LBP (Balagué et al. 1999; Pasanen et al. 2016; Rossi et al. 2016). Many studies on early sport specialization have indicated that concentration in only one sport activity in youth may predispose to overuse injuries including LBP (Fabricant et al. 2016; Myer et al. 2015). At the same time, in a population-based sample of Finnish adolescents aged 15 to 16 years, participation in several sport activities, i.e., being a generalist, seemed to provide potential protection from the harmful effects of a single risk sport (Auvinen et al. 2008). However, the study by Auvinen et al. was cross-sectional and the results considering LBP were not statistically significant. Two other studies detected no association between participation in several sports and back pain in adolescence (Mogensen et al. 2007; Moradi et al. 2015). Spinal pain (including low back, mid back, and neck pain) had no association with the number of sporting hours, the number of sports, or sport participation in general in a cross-sectional study of Danish adolescents aged 12 to 13 years (Mogensen et al. 2007). A review study investigating the risk factors for LBP among adolescent and adult athletes summarized that participation in other sports (i.e., other than the primary sport) has no association with LBP based on moderate evidence from two prospective studies (Moradi et al. 2015). Overall, the evidence on the association between a diversity of sport activities and LBP is scarce and mostly derived from adolescent and athlete samples.

2.4.2 NECK–SHOULDER REGION PAIN

The evidence for the relationship between LTPA and NSP is limited and inconsistent in adult populations (Sitthipornvorakul et al. 2011). A review article found moderate evidence that exercise may prevent NSP (Jensen and Harms-Ringdahl 2007). Yet, in a large sample of Swedish workers, only previously pain-free workers were protected from chronic neck pain by participation in LTPA (Palmlof et al. 2016). Previous evidence has indicated no association between LTPA and NSP in school-aged children (Briggs et al. 2009; Sitthipornvorakul et al. 2011). Yet, a Canadian study suggested that adolescent athletes have less neck pain compared to non-athlete peers (Legault et al. 2015), whereas in a Japanese non-athlete population the risk of NSP increased with participation in organized sport activities (Kamada et al. 2016). A Finnish population-based study found that high-level LTPA was associated with a higher prevalence of NSP among girls but not among boys (Auvinen et al. 2007). In a Chinese survey, high school students who participated in LTPA more than 60 min, 1–4 days per week had less NSP, whereas those who exercised for longer or shorter periods had more NSP. The differences in previous and recent results may be partially confounded by the increasing use of mobile touch screen devices among adolescents (Toh et al. 2017). In summary, no specific dose or intensity of LTPA has been found safe and effective in the prevention of NSP, yet moderate activity seems most recommendable.

Some potential risk sports, as well as some potentially beneficial sport activities, have been identified in the studies on the prevalence of NSP among adolescents and athletes. In population-based adolescent samples, participation in strength and extreme sports among boys, downhill skiing among girls, and horseback riding in sex-pooled analysis have been associated with increased risk of NSP (Auvinen et al. 2008; Guddal et al. 2017; Mogensen et al. 2007). Unlike with LBP, team sports, such as soccer and Finnish baseball, have showed negative associations with NSP in adolescence (Auvinen et al. 2008; Guddal et al. 2017; Mogensen et al. 2007). Yet, in a study of Iranian young athletes (aged 12 to 20), basketball players had the highest risk for neck pain, followed by volleyball players (Farahbakhsh et al. 2018). Studies of NSP among solely adult athletes are scarce and have considered only a few sports (Fett et al. 2019; Noormohammadpour et al. 2018). Fett et al. (2019) studied athletes (aged 13 to 34) who had exposure to repetitive overhead activity and found a significant difference in the one-year prevalence of neck pain between badminton (26%) and handball (48%) players, but no difference between athletes and physically active controls. A Swedish study including 75 male athletes (divers, weight-lifters, wrestlers, orienteerers and ice-hockey players) and 12 non-athletes (aged 10 to 41 years) found the highest one-year prevalence of NSP among wrestlers (75%) and ice-hockey players (65%) (Jonasson et al. 2011). Another Swedish study among sky divers reported neck pain as the most common musculoskeletal pain related to parachute opening shock (Nilsson et al. 2013). Similarly, NSP was the most frequent location of musculoskeletal pain among Norwegian fitness instructors (Bratland-Sanda et al. 2015). In terms of endurance sports, two American studies have investigated neck pain among triathletes and reported life-time prevalence around 48% (Villavicencio et al. 2007; Villavicencio et al. 2006), which is similar to the general population (Fejer et al. 2006a). Among triathletes, overuse and inappropriate positions related to cycling have been considered to be significant factors in the development of neck pain (Deakon 2012). In a sample of amateur long distance bicyclists attending a 500 mile race for 8 days, 20.4% developed NSP (Weiss 1985). Among Finnish adolescent boys, frequent participation (twice a week or more) in cycling was also related to a higher prevalence of neck pain, whereas frequent participation in cross-country skiing was related to less neck pain in boys and girls (Auvinen et al. 2008). Among Norwegian adolescents, participation in endurance sports was associated with less NSP among both boys and girls (Guddal et al. 2017). In the review by Noomohammadpour et al., orienteerers had the lowest one-year prevalence of neck pain, 38% (Jonasson et al. 2011; Noormohammadpour et al. 2018). Overall, the evidence on associations between specific sport activities and NSP is still scant, among both adolescents and adults.

Even less evidence exists on the association between the quantity of sport activities participated in and prevalence of NSP. In the Finnish adolescent sample, boys who engaged in several sport activities, i.e., generalists, reported less neck pain compared to those with less diverse sport participation (Auvinen et al. 2008). In contrast, as mentioned at the end of the previous section 2.4.1., among Danish adolescents spinal pain, including low and mid back, as well as neck pain, was not associated with the number of sports (Mogensen et al. 2007). However, the differing results could be partially due to different outcome measures. More studies, especially with longitudinal design, are required to confirm the association between participation in several sport activities and NSP.

2.5 SUMMARY OF LITERATURE

An increasing amount of evidence on childhood and adolescent sport participation has addressed the potential harms of early specialization, including overuse injuries and burnout (Fabricant et al. 2016; Myer et al. 2015). Early diversification instead of specialization has shown positive implications to long-term sport involvement, which should be the ultimate goal of sport participation in youth (Brenner et al. 2007; Côté and Vierimaa 2014). According to tracking studies, those who engage in higher levels of LTPA in adolescence tend to also be most active in adulthood (Telama 2009), yet most of the LTPA trajectories are declining or consistently low (Lounassalo et al. 2019). This is worrisome since sustained and regular physical activity is key to several health benefits and maintained fitness and an independent life in the long-term (Piercy et al. 2018; World Health Organization 2010). Some evidence (summarized in Table 2) has indicated that participation in several sport activities in adolescence is associated with higher levels of LTPA later in adolescence and adulthood (Aarnio et al. 2002; Cleland et al. 2012; Engström 2008; Robertson-Wilson et al. 2003). Only one prior study has considered both the quantity and quality of sport activities in the longitudinal design (Kjonniksen et al. 2008).

Spinal pain also tends to be a lifelong phenomenon and is associated with LTPA. The recurrent and multifactorial symptoms often start already in adolescence and spike in mid-adulthood, causing enormous burden for individuals and societies worldwide (J. Hartvigsen et al. 2018; Hogg-Johnson et al. 2008; Vos et al. 2016). Generally, exercise is effective in secondary prevention of spinal pain (Babatunde et al. 2017; "Low Back Pain: Current Care Guidelines" 2017; "Neck Pain: Current Care Guidelines" 2017), but its effect on primary prevention of spinal pain remains uncertain (Landmark et al. 2013; Palmlof et al. 2016; Shiri and Falah-Hassani 2017; Heneweer et al. 2011). Especially in adolescence, however, high-level and high-intensity sport participation with repetitive movements may lead to overuse, which is a common cause of spinal complaints (Balagué et al. 1999; Rossi et al. 2016). Studies among athletes have identified some risk sports for LBP and NSP, including ball games, contact sports, gymnastics, cycling, rowing, and cross-country skiing (Daniels et al. 2011; Farahbakhsh et al. 2018; Fett et al. 2017; Jonasson et al. 2011; Noormohammadpour et al. 2018; Triki et al. 2015; Villavicencio et al. 2006). Simultaneously, one population-based study has suggested that participation in several sport activities may protect from the risks of single-sport participation in adolescence (Auvinen et al. 2008). Similar evidence on adult populations is lacking since current evidence on sport activities and spinal pain is focused on non-specific LBP in adolescent and athlete samples. Yet, radiating LBP is known to be more troublesome and more often chronic and disabling (Kongsted et al. 2012; Konstantinou and Dunn 2008). Recent studies on LBP have suggested that more specific analyses on different types of LBP are needed (J. Hartvigsen et al. 2018; Stynes et al. 2016). Thus far, only a few population-based studies have investigated the associations between the diversity of sport activities and spinal pain in general adult populations, especially in longitudinal settings.

Furthermore, the evidence shows that familial factors (such as genes and family environment) influence LTPA behavior, as well as the perceived spinal pain (Lightfoot et al. 2018; Nielsen et al. 2012). In theory the same familial factors may confound the associations of the diversity of sport activities with LTPA levels and spinal pain. Twin studies provide a means to test this potential confounding by familial factors, yet none of the previous studies considering the diversity of sport activities has used a genetically informative twin sample.

3 AIM OF THE STUDY

The main aim of the thesis was to determine whether diversity in leisure-time sport activities provides additional health benefits independent of LTPA level compared to single-sport participation. In order to test the hypothesis that participation in a higher number and different types of sport activities is associated with higher LTPA levels and less spinal pains in adulthood, three studies from different viewpoints were conducted using a genetically informative dataset which enabled testing for confounding by familial factors.

The specific objectives were the following :

I. To investigate the relationship between the diversity of leisure-time sport activities in adolescence and the level of leisure-time physical activity in adulthood (I)

II. To explore the associations of diversity of leisure-time sport activities during adolescence and adulthood with low back and neck–shoulder region pain in adults (II)

III. To examine the association between the diversity of leisure-time sport activities and type of low back pain in adulthood (III)

4 MATERIAL & METHODS

4.1 FINNTWIN16 STUDY PARTICIPANTS

The FinnTwin16 study is a nationwide cohort study of the health behaviors of Finnish twins and their families (Kaprio et al. 2002). Twin pairs born in 1975–79 were identified from the Central Population Register and the first survey wave took place in 1991–1995, within 60 days of the twins' 16th birthdays. In addition, twins who were born in the last 3 months of 1974 formed a pilot sample for assessing the functionality of the questionnaire at all waves. The first wave yielded a high pairwise response rate of 88% (N=2773 for complete pairs). The following survey waves took place when the twins were around age 17 (mean 17.1, range 17.0–18.0), 18.5 (18.6, 18.3–19.4), 24 (24.5, 21.0–28.6), and 34 (34.1, 31.9–37.4) (Figure 1). The second survey wave, conducted in 1992–96, was responded to by 95% of its recipients (N=5445). The latest, fifth survey wave was a web-based questionnaire conducted between 2010 and 2012 with a response rate of 72% (N=4246) (Kaprio 2013; 2006; Kaprio et al. 2002).

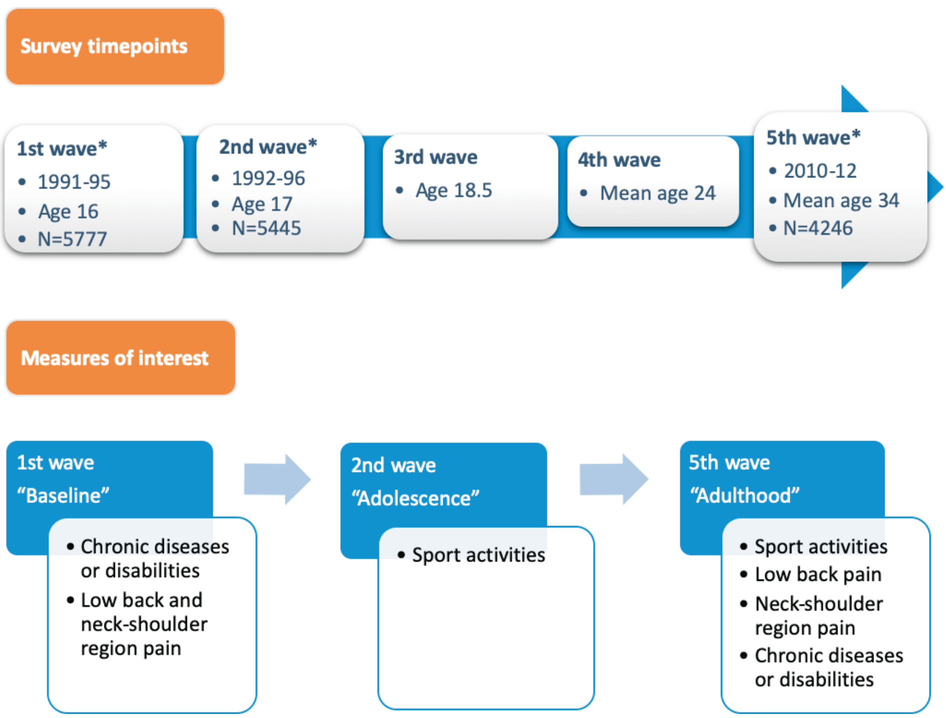

Figure 1 Survey timepoints of the FinnTwin16 study and measures of interest.

In the studies of this thesis, I used data from the first (baseline), second (adolescence), and fifth (adulthood) survey waves of the FinnTwin16 study (Figure 1). All studies (I, II, III) primarily included only individuals who had answered the items of interest and participated in LTPA at least once a month and reported at least one sport activity at the wave of interest. This restriction was due to the aim to compare health benefits between participation in only one sport and several sport activities. The chosen sample included 5096 individuals in adolescence and 3734 in adulthood. Yet, I have included the inactive individuals in some of the sensitivity analyses described later on (I, II). In baseline and adulthood, individuals answered a question "Do you have any longterm illness or disability which hinders your daily activities?" Exclusion criteria included individuals who reported a medical condition that hinders daily activities and, thus, could prevent participation in PA. These medical conditions included motor disabilities, chronic diseases (osteoarthritis, visual impairments, etc.), and some mental disorders (depression, schizophrenia, etc.) (Aaltonen et al. 2013). In addition, I excluded women who were pregnant during the fifth wave in the studies considering both LTPA and LBP since pregnancy may both reduce the ability to engage in PA as well as cause LBP (II, III). Moreover, studies I and II utilized the unique nature of twin data by comparing discordant twin pairs. The determination of zygosity has employed a validated questionnaire method (Sarna et al. 1978), supplemented with genetic marker information for some twin pairs.

Study I, which investigated the relationship between the diversity of leisure-time sport activities in adolescence and LTPA levels in adulthood, included 3651 individuals who had replied to PA-related questions in both the second and fifth waves. There were 409 individuals excluded due to medical conditions that hinder daily activities in baseline or adulthood. Further, primary analyses were conducted among those individuals who had participated in LTPA at least once a month and reported at least one sport activity in adolescence, as well as provided information on all confounders in both adolescence and adulthood surveys. Additionally, to investigate possible additional confounding due to shared genetic and environmental factors, I identified twin pairs (N=23) who were discordant for both the number of leisure-time sports activities during adolescence (i.e., one twin engaged in several sport activities while their co-twin engaged in only one) and for LTPA level in adulthood (i.e., one twin in the most active quartile and their co-twin in the least active quartile). Of the 23 double-discordant twin pairs, 4 were monozygotic (MZ) and 19 dizygotic (DZ).

Study II, which explored low back and neck–shoulder region pain symptoms in adults in relation to the diversity of leisure-time sport activities during adolescence and adulthood, included 3201–3207 active individuals for cross-sectional analyses and 3005–3013 for longitudinal analyses. Exclusion from cross-sectional analyses occurred for those who reported a medical condition that hindered daily activities in adulthood (n=342) and women who were currently pregnant (n=160). From longitudinal analyses, I also excluded those who reported a medical condition that hindered daily activities at baseline (n=155). Furthermore, to explore the possible shared genetic and environmental influences affecting the relationship between leisure-time sport activities and LBP or NSP, I identified twin pairs discordant for the frequency of LBP (n=507 (171 MZ, 336 DZ)) and NSP (n=579 (203 MZ, 376 DZ)).

Study III examined the association between the diversity of leisure-time sport activities and the type of LBP in adulthood and included 1621 individuals who had reported PA participation at least once a month and at least one sport activity, as well as had replied to all LBP items in the fifth wave. Those who had reported a medical condition that hindered daily activities and women who were currently pregnant were excluded.

4.2 MEASUREMENTS IN FINNTWIN16

4.2.1 DIVERSITY OF LEISURE-TIME SPORT ACTIVITIES (I, II, III)

The main characteristic of this thesis and the independent variable in all three studies was the diversity of leisure-time sport activities, which I modeled with the quantity (i.e., number) and quality (i.e., type) of sport activities participated in. As described in the review of the literature, I chose to use the term “sport activities” in the aim to separate this specific dimension of LTPA from competitive sports. Other studies have also used terms such as “discipline” and “physical activities” to describe different sports in similar contexts (Kjonniksen et al. 2007, Rottensteiner et al. 2017).

Both the quantity (I, II, III) and quality (I, III) of sport activities were based on the multiple-choice question in the second and fifth survey waves (Figure 1). The quantity of sport activities was a sum variable including all sport activities participated in and reported on during the second and fifth waves, ranging from 0 to 15 and 20, respectively. The number of sport activities lacked a normal distribution and, thus, I made 5 categories as follows: 1, 2, 3, 4, and 5 or more sport activities. The same categorization took place during the second and fifth waves in an aim to enable proper comparison between the timepoints.

The quality of sport activities had two different categorizations due to differing research objectives. In study I, I investigated whether participation in a specific type of sport results in higher LTPA levels in adulthood. The categories were endurance (e.g., walking, running, swimming, skiing), power (e.g., gym, weight lifting, body building), games (e.g., ball and racket games), and others (e.g., dance, martial arts, motor sports). Similar categories had been previously used in a study based on the FinnTwin16 sample (Aarnio et al. 2002). In study III, I examined the relationship between different types of sport activities and type of LBP using the following categories: walking, endurance sports, strength sports, single games, team games, technical sports, aesthetic sports, combat sports, and body care activities. This categorization was also inspired by a previous work in the field (Guddal et al. 2017).

4.2.2 LEISURE-TIME PHYSICAL ACTIVITY (I, II, III)

All survey waves included items on LTPA, inquiring about at least the frequency of LTPA and perceived fitness. In the second and fifth wave questionnaires, twin individuals also replied to a multiple-choice question on what type of sports they had participated in during their leisure-time. The multiple-choice question listed 18 (second wave) and 26 (fifth wave) different sport activities and included an open field for reporting up to three more activities. Individuals were able to report participation in several sport activities and all responses were coded and entered separately.

Adulthood questionnaires (i.e., fourth and fifth waves) included more items on LTPA, inquiring about the frequency, mean intensity and mean duration of LTPA sessions, as well as items on active commuting and the physical demand of work or studies. Using the information on frequency, mean intensity and mean duration of LTPA sessions, as well as active commuting, we were able to calculate leisure-time Metabolic Equivalent of Task (ltMET) indices (Ainsworth and Levy 2004) as shown in Figure 2. First, all intensities received a multiple of the resting metabolic rate (MET score) based on previously estimated values as follows: 4 (for exercise intensity corresponding to walking), 6 (interval walking and jogging), 8.3 (jogging), and 11 (running) (Ainsworth et al. 2011). Since active commuting is popular and may form the majority of LTPA among Finnish adults, it was included in the calculation and received a MET value of 4 (usually walking). Finally, the calculation was: (LTPA frequency x mean duration x mean intensity) + (active commuting frequency [assumed 5 days/week] x mean duration x intensity) = ltMET index (ltMET-h/day).

In the analyses, we used ltMET index both as a categorized outcome variable (I) and as a float covariate (II & III). The categorization took place, since the ltMET index had a skewed distribution and none of the possible transformations (including logarithmic and square root transformations) to normalize the distribution provided an adequate fit for the data. Thus, I divided individuals into activity quartiles in an aim to create nearly equal-sized categories that allowed for evaluation of class-specific effects. The quartile cut points were 1.53, 3.78, and 5.83 ltMET-h/day for males, and 1.49, 2.99, and 5.28 ltMET-h/day for females. Thus, the lowest ltMET-quartile included those who did not meet the WHO recommendation for weekly PA (equal to 1.5 MET-h/day) (World Health Organization 2010).

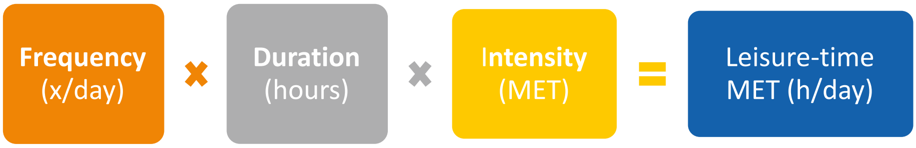

Figure 2 The calculation of leisure-time physical activity as leisure-time MET-h/day.

MET, metabolic equivalent of task.

4.2.3 LOW BACK PAIN (II, III)

Information on spinal pain was available from first, third, fourth, and fifth wave surveys. The first, third, and fifth wave included a question "During the past 6 months, have you had any of the following symptoms, and if yes, how often?" In the first and third wave, one of the symptoms was "back or neck pain", whereas in the fifth wave they were separately as "low back pain" and "neck-shoulder region pain". The response options were identical at all waves as follows: never/seldom, approximately once a month, approximately once a week, and nearly every day. In an aim to compare individuals with rare, occasional, and frequent pain, I made a new categorization for the analyses: never/seldom (reference group), monthly (approximately once a month), and weekly (approximately once a week or nearly every day). The frequency of LBP symptoms during the fifth wave was used in both Study II and III and information on the first wave to adjust the longitudinal analyses in Study II.

The fifth wave survey included additional items on spinal pain (see Appendix). The first one (question 12) was similar to the baseline questionnaire but had separate items inquiring about low back and neck–shoulder region pain during the past 6 months. The second item (question 13) was "Have you ever had a backache lasting for a day or longer?" with the following options: "never → move to question 15", "1–2 times", "3–9 times", and "over 10 times". The third item (question 14) was a follow-up question for those who had ever had a back pain episode lasting more than one day: "What was your backache like when it was at the worst?" The options were: "sciatica (back pain that radiates to lower limb)", "lumbago (sudden attack of back pain)", or "other back disease, please specify". Based on all three questions (12–14), I created a restricted sample with the following categories: 1) radiating LBP = at least one back pain period over one day + LBP at least once a month during the past six months + the worst pain like sciatica, 2) non-radiating LBP = at least one back pain period over one day + LBP at least once a month during the past six months + the worst pain like lumbago, 3) reference category = no LBP lasting longer than one day and no weekly LBP (III).

The fourth wave included items similar to questions 13 and 14 but lacked the question on frequency of LBP. Thus, in aiming to obtain a wider perspective on spinal pain symptoms, as well as a longer follow-up and higher rates of symptoms, I only used the information on the fifth wave that also included information on different sport activities participated in.

4.2.4 NECK–SHOULDER REGION PAIN (II)

Information on neck pain was available on first, third, and fifth wave surveys. The first and third wave included a combination item on whether twin individuals had had back and/or neck pain during the past six months with the following options: never/seldom, approximately once a month, approximately once a week, and nearly every day. This item made it impossible to know if they had both back and neck pain, only monthly neck pain, or maybe weekly neck pain and monthly back pain. Thus, back and neck pain reported at baseline (first wave) was only adjusted for in the longitudinal analyses of Study II.

In the fifth wave, a similar question had separate items for low back pain and neck–shoulder region pain, but the response options were identical: never/seldom, approximately once a month, approximately once a week, and nearly every day. The frequency of NSP in adulthood was one of the outcomes in Study II.

4.2.5 COVARIATES

In all three studies, the inclusion of covariates was a stepwise process. The first step was to identify potential covariates from the literature (Bauman et al. 2012; J. Hartvigsen et al. 2018; Hogg-Johnson et al. 2008; Parreira et al. 2018). The second step was to check the availability of equivalent variables in the FinnTwin16 data. The final step was to test which of the potential and available covariates had a significant association with both main variables and, thus, should be included as confounders (Bauman et al. 2012). Fortunately, the FinnTwin16 study included information on several known correlates and confounders of physical activity behavior and spinal pain, including general health status, mental health, sleeping problems, education level, type of work, smoking, BMI, having children, and being pregnant (females only). Most of the covariates included in the studies were measured during the fifth wave simultaneously with the outcomes of interest.

General health status was reported with following options: poor, rather poor, mediocre, good, or very good (I, II, III). The mental health assessment was based on the 12-item General Health Questionnaire (GHQ-12), which was scored with the Likert method (Goldberg et al. 1997) (II, III). Sleeping problems, including both troubles falling asleep and waking up during the night, were reported as follows: never/seldom, approximately once a month, approximately once a week, and nearly every day (II, III). The educational level (i.e., the highest accomplished degree) had six categories: junior high school, vocational school, college level, senior high school, university of applied sciences, or university (I) that were also categorized as compulsory, vocational secondary, academic secondary, or tertiary (university or polytechnic college) (II, III). The work activity level was categorized as light (sedentary/some walking), heavy (frequent walking/lifting/digging, etc.), and not working/studying at the moment (I, II, III). Smoking status had four categories: current, occasional, former, and never smokers, which I used as such in Study II and III, but as a dichotomy: ever/never smokers, in Study I. BMI (kg/m^2) based on self-reported height and weight (II, III).

Moreover, the longitudinal analyses of Study I were adjusted with the frequency of LTPA in adolescence (times/week), whereas analyses of Study II and III were adjusted with the ltMET index in adulthood. The purpose of adjusting the analyses with the frequency or level of LTPA was to account for the possible confounding that the benefits of participation in several sport activities would only be due to the increased frequency or level of LTPA. Additionally, the longitudinal analyses of Study II were adjusted with baseline pain symptoms in an aim to account for the possible confounding that spinal pain at age 16 would prevent participation in sport activities at age 17 or correlate with spinal pain at age 34.

Thus, we considered physical activity level in adolescence, health status in adulthood, and education as regular scale variables, but we used them as continuous variables to explore trend effects. Work activity level, however, was used as a categorical variable to detect differences between sedentary and heavy physical work. Smoking status was used both as a dichotomy (I) and a categorical variable (II, III) as described above. In addition, we treated some potential adult confounding factors as dichotomous variables: having children (yes/no), and currently pregnant at follow-up (yes/no, females only). Participants with missing information on confounders were excluded from the analyses.

4.3 ETHICS OF THE STUDY

All three studies followed the accepted ethical standards and the Declaration of Helsinki. The Ethics Committees of the Hospital District of Helsinki and Uusimaa and the Institutional Review Board of Indiana University, Bloomington, IN, USA approved the FinnTwin16 study. The Ethics Committee of the Central Finland Hospital District accepted the fifth wave of data collection. At all waves of the FinnTwin16 study, twins (or their parents) provided their informed consent by returning the questionnaire.

4.4 STATISTICAL METHODS

For statistical analyses, I used Stata versions 13.1 and 15.0 (Stata Corp 2013; 2017). In all analyses the statistical significance level was set at $p<0.05$. Variable distributions and normality were examined by computational and visual means including cross-tabulations and histograms, as well as independent t-tests for continouos variables and chi-squared tests for categorical variables. Both the number of sport activities and ltMET index lacked a normal distribution, whereas the frequency of LBP and NSP, as well as the type of LBP, were categorical variables by nature. During Study I, I tried various regression models and different normality transformations for the ltMET index but finally chose the multinomial logistic regression analysis as the best fitting statistical approach. When making the categorization for the number of sport activities and LTMET index, I aimed to keep the number of categories informative and reasonable, as well as the number of study participants effectively equal between categories in order to maximize statistical power.

4.4.1 INDIVIDUAL-BASED ANALYSES

All studies (I, II, III) had categorical outcome variables, thus, I conducted binomial and multinomial logistic regression analyses. Both cross-sectional (II, III) and longitudinal (I, II) logistic regression provided odd ratios (OR) and 95% confidence intervals (CI). When I analyzed the twins as individuals, I used robust estimators of variance to control for the clustering of correlated observations within a twin pair (Williams 2000).

In all studies, the likelihood ratio test comparing nested models with and without the interaction term was conducted for all potential confounders including sex. Interaction testing led to partly sex-pooled (II, III) and partly separate analyses for males and females (I, III), the latter being the more used approach in the field due to known sex differences in LTPA patterns (Hallal et al. 2012). Other covariates demonstrated no significant interactions and analyses required no further stratifications.

The primary analyses included only individuals with at least monthly participation in LTPA and one reported sport activity, and without chronic medical conditions that hinder daily activities. Further sensitivity analyses also included the inactive (I, II) and separately considered those excluded due to medical conditions and the very active (achieving 11 ltMET-h/day) individuals to test the robustness of the models (II). The results from the analyses including inactive individuals who participated in physical activity less than once a month and/or did not report any sport activity were appended as supplemental material for the published articles (I, II). Other sensitivity analyses were only shortly reported on in the manuscripts (I, II, III).

4.4.2 WITHIN-PAIR ANALYSES

The unique nature of twin sample enables to assess whether the association is confounded by unmeasured familial (such as genes and family environment) factors. Classical twin study design (Plomin et al. 2000) relies on the knowledge that monozygotic (MZ) twins share identical genomes (apart from sporadic mutations), whereas dizygotic (DZ) twins share on average half of their segregating genes. In addition, twin pairs are usually reared together and thus share a similar childhood environment. By examining an association first within the whole sample including (twin) individuals and then among DZ and finally among MZ twin pairs, a different degree of genetic variation may be accounted for. Thus, if individual-based analyses show an association which attenuates in MZ and DZ within-pair analyses, the familial factors may confound the association. When the association attenuates even more in MZ than DZ pairs, genetic influences may be the confounder.

In Study I, a conditional logistic regression model provided the means to evaluate possible confounding due to familial factors (Thomas 2004). Analysis included only the extreme categories (i.e., the least and most active ltMET quartiles). Due to this requirement for extreme discordance in outcome, the within-pair analysis adjusted for sex included only 23 baseline- and outcome-discordant twin pairs (4 MZ pairs and 19 DZ pairs). Further sex-specific analyses I conducted separately for 7 twin brother pairs and 5 twin sister pairs.

In Study II, I used a relatively new method, the fixed effects multinomial logistic regression model (Pforr 2014), to calculate the ORs for monthly or weekly LBP and NSP per difference of one sport activity participated in among the discordant twin pairs. In other words, ORs < 1 indicated that the co-twin who participated in a higher number of sport activities was less likely to have monthly or weekly LBP or NSP, whereas ORs > 1 indicated that the co-twin who participated in a higher number of sport activities was more likely to have monthly or weekly LBP or NSP than the co-twin who participated in fewer sport activities. The analyses included 507 twin pairs who were discordant for LBP (171 MZ, 336 DZ) and 579 twin pairs discordant for NSP (203 MZ, 376 DZ).

5 RESULTS

As previously described in chapter 4.1, the chosen adult sample included 3734 individuals. The characteristics of this sample with at least monthly participation in LTPA are presented in Table 3. The sample included more females (57.0%) than males (43.0%) who differed from each other in several traits but had an equal mean number of sport activities participated in (3.4, standard deviations (SD) 1.9–2.0). Yet, males had on average higher levels of ltMET (4.7 MET-h/day, SD 3.6) than females (4.2 MET-h/day, SD 3.6). Females reported both more weekly LBP (19.5%) and NSP (35.1%) than males (17.0% and 19.6%, respectively) in adulthood. When type of LBP was considered, females reported more often radiating LBP than males (30.7% vs 23.7%), whereas males reported more frequently non-radiating LBP than females (37.0% vs. 25.3%).

In adjusting variables, males and females differed systematically. Females more often reported poor general (2.7% vs 1.6%) and mental health (GHQ-12 score 11.0 (SD 5.5) vs 10.2 (5.1)), as well as weekly sleep problems (32.2% vs 27.3%). Yet, males were more often current smokers (30.2% vs 22.0%), more seldom had tertiary education (46.1% vs 57.1%) and more often had physically demanding work (27.5% vs 23.7%). More females than males reported having children (65.1% vs 56.9%) in their mid-thirties.

Some of the results are presented only in this thesis and not in original publications, whereas some results are only shown in original publications to avoid too much repetition. The results are shown in the order of the publications due to visual means.

Table 3 Characteristics of the chosen adult sample, by sex

	Male (n=1606)	Female (n=2128)	p-value*
Age (y) – mean (SD)	34.0 (1.2)	34.0 (1.2)	0.62
Number of sport activities – mean (SD)			
In adulthood (age 34)	3.4 (2.0)	3.4 (1.9)	0.83
In adolescence (age 17)	3.3 (2.2)	3.3 (2.0)	0.64
Leisure-time PA (MET-h/day) – mean (SD)	4.7 (3.6)	4.2 (3.6)	<0.001
- **Average frequency of LTPA (1/day)**	0.3 (0.2)	0.4 (0.3)	0.002
- **Average duration of LTPA (h)**	1.2 (0.5)	1.2 (0.4)	<0.001
- **Average intensity of LTPA (MET/h)**	8.2 (2.4)	6.9 (2.4)	<0.001
Low back pain – n (%)			0.16
- **Never/seldom**	856 (53.9%)	1105 (52.3%)	
- **Monthly**	463 (29.1%)	595 (28.2%)	
- **Weekly**	270 (17.0%)	411 (19.5%)	
Back pain episode over one day – n (%)	1241 (77.5%)	1427 (67.1%)	<0.001
Type of back pain at the worst – n (%)			<0.001
- **Radiating pain**	287 (23.7%)	434 (30.7%)	
- **Non-radiating pain**	448 (37.0%)	357 (25.2%)	
- **Other back disease**	475 (39.3%)	625 (44.1%)	
Neck–shoulder region pain – n (%)			<0.001
- **Never/seldom**	753 (47.3%)	644 (30.4%)	
- **Monthly**	526 (33.1%)	730 (34.5%)	
- **Weekly**	312 (19.6%)	742 (35.1%)	
Health status – n (%)			<0.07
- **Very or fairly good**	1340 (83.7%)	1768 (83.2%)	
- **Average**	236 (14.7%)	300 (14.1%)	
- **Fairly or very poor**	26 (1.6%)	58 (2.7%)	
BMI (kg/m²) – mean (SD)	25.6 (3.4)	23.9 (4.4)	<0.001
GHQ-12 score – mean (SD)	10.2 (5.1)	11.0 (5.5)	<0.001
Sleeping problems – n (%)			0.002
- **Never or seldom**	745 (46.8%)	877 (41.5%)	
- **Monthly**	412 (25.9%)	556 (26.3%)	
- **Weekly**	435 (27.3%)	680 (32.2%)	
Smoking status – n (%)			<0.001
- **Current**[a]	481 (30.2%)	466 (22.0%)	
- **Former**	377 (23.7%)	442 (20.9%)	
- **Never**	735 (46.1%)	1208 (57.1%)	
Education level – n (%)			<0.001
- **Compulsory**	47 (2.9%)	45 (2.1%)	
- **Vocational secondary**	565 (35.2%)	571 (26.8%)	
- **Academic secondary**	211 (13.2%)	300 (14.1%)	
- **Tertiary (university or polytechnic college)**	782 (48.7%)	1212 (57.0%)	
Work activity level – n (%)			<0.001
- **Light**[b]	1096 (68.3%)	1306 (61.5%)	
- **Heavy**[c]	441 (27.5%)	504 (23.7%)	
- **Not working or studying**	67 (4.2%)	314 (14.8%)	
Having a child – n (%)	910 (56.9%)	1381 (65.1%)	<0.001
Currently pregnant – n (%)		170 (8.0%)	

SD, standard deviation; GHQ-12, the 12-item General Health Questionnaire; BMI, body mass index; PA, physical activity; LTPA, leisure-time physical activity; MET, metabolic equivalent of task.

[a]Including occasional smokers
[b]Sedentary/some walking
[c]Frequent walking/lifting/digging, etc.
*p-values based on independent t-tests for continouos variables and chi-square tests for categorical variables

Study I investigated the relationship between the diversity of leisure-time sport activities in adolescence and LTPA levels in adulthood. Figure 3 presents the cross-tabulation–derived distributions on how individuals with 1, 2, 3, 4, and 5 or more sport activities in adolescence divided into lt-MET quartiles in adulthood, by sex. The differences are visually most distinct between 1 and 5 or more sport activities participated in during adolescence, both for males and females. Individuals with 5 or more sport activities in adolescence were clearly more often in the most active quartile in adulthood.

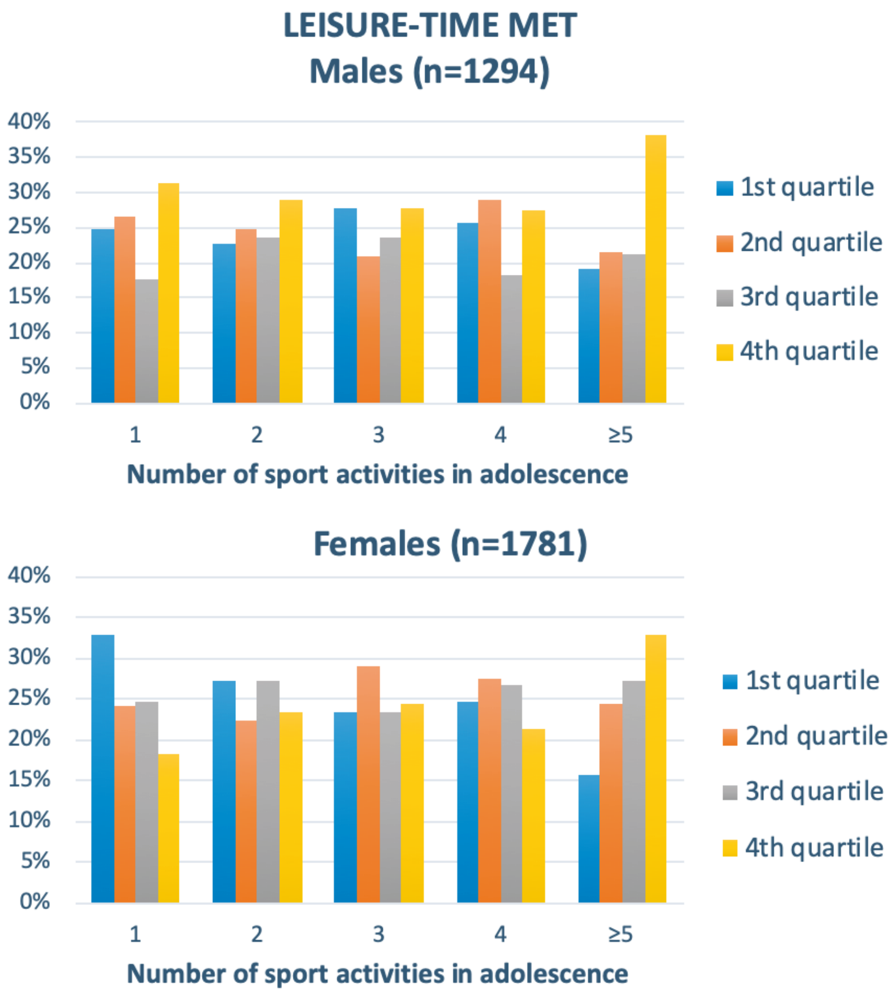

Figure 3 Leisure-time MET quartiles in adulthood by the number of sport activities in adolescence. MET, metabolic equivalent of task.

Study II explored low back and neck–shoulder region pain symptoms in adults in relation to the diversity of leisure-time sport activities during adolescence and adulthood. Figure 4 shows the cross-sectional results, i.e., the frequencies of LBP and NSP by the number of sport activities participated in during adulthood. In their mid-thirties, twin individuals reported clearly less LBP than NSP. The frequency of LBP decreased more clearly than the frequency of NSP, while the number of sport activities participated in during adulthood increased. Figure 5 shows the longitudinal results, i.e., the frequencies of LBP and NSP by the number of sport activities participated in during adolescence. When the number of sport activities in adolescence increased, the share of weekly LBP in adulthood decreased, but no similar, clear pattern existed for the frequency of NSP in adulthood.

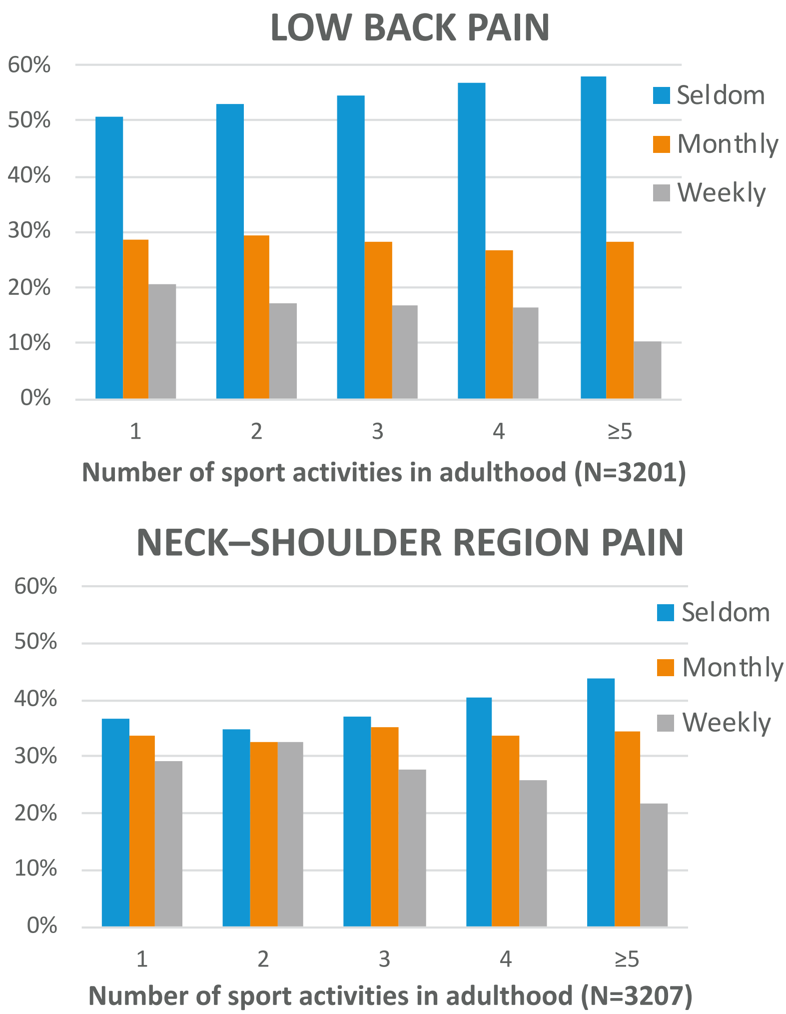

Figure 4 Frequency of low back and neck-shoulder region pain by the number of sport activities in adulthood.

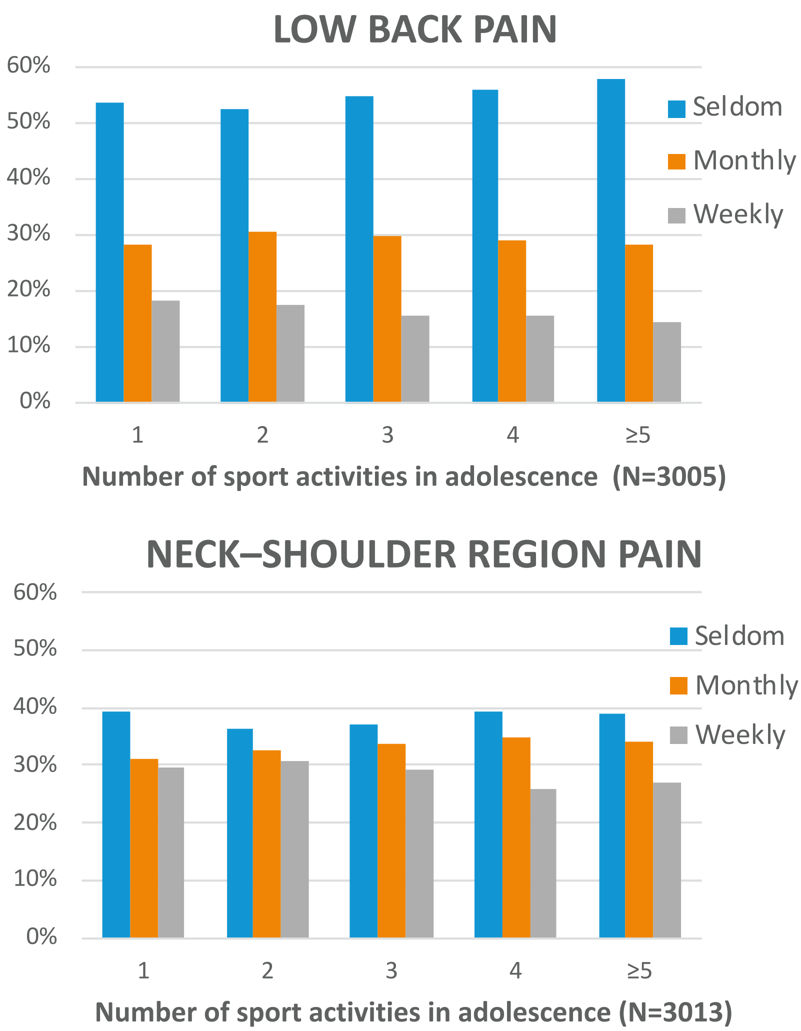

Figure 5 Frequency of low back and neck–shoulder region pain by the number of sport activities in adolescence.

Study III examined the association between the diversity of leisure-time sport activities and type of LBP in adulthood. Figure 6 displays the proportions of individuals with no >1 day episodes of back pain, with radiating LBP, and with non-radiating LBP by the number of sport activities participated in during adulthood. In the restricted sample (described in section 4.2.3), males reported proportionally more >1 day episodes of back pain. Females more often reported radiating than non-radiating LBP, and the proportion with radiating LBP clearly decreased when the number of sport activities increased. Males had a similar pattern for non-radiating LBP, which they reported more often than females.

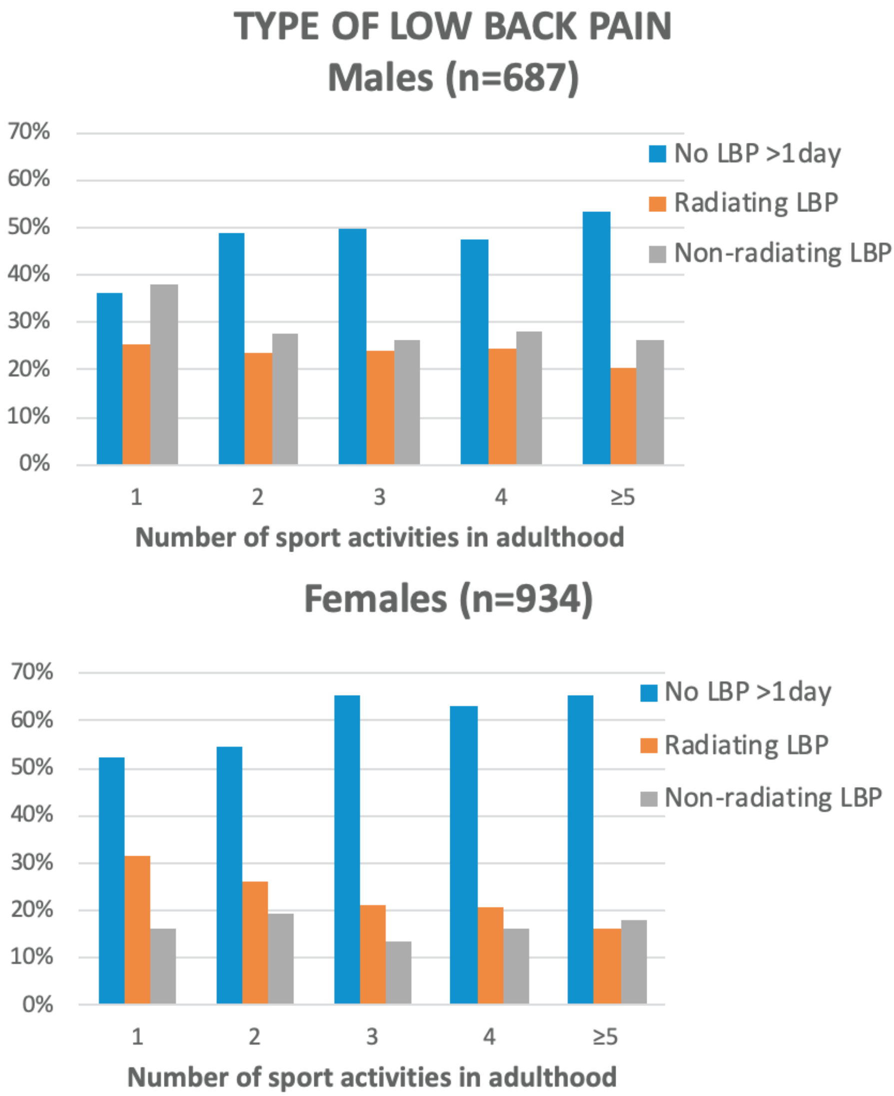

Figure 6 Low back pain classes by the number of sport activities participated in during adulthood. (Study III). LBP, low back pain.

5.1 DIVERSITY OF SPORT ACTIVITIES IN ADOLESCENCE AND LEISURE-TIME PHYSICAL ACTIVITY IN ADULTHOOD

In study I, the multinomial logistic regression analyses among twin individuals revealed that participation in five or more sport activities compared to one sport activity in adolescence was associated with higher LTPA level in adulthood, among females. Figure 7 presents the full results which showed that females who participated in five or more sport activities in adolescence were significantly more likely to be included in any of the more active ltMET quartiles (i.e., 2nd, 3rd or 4th quartile) with the following ORs (95% CIs): 2.05 (95% CI 1.25–3.38), 2.00 (95% CI 1.23–3.28), and 3.10 (95% CI 1.79–5.42), respectively. These associations were independent of the frequency of participation in sport activities in adolescence. Similar types of associations existed among males in the basic model for the 3rd and 4th quartile compared to the 1st quartile, with ORs 1.88 (95% CI 1.10–3.22) and 1.71 (95% CI 1.08–2.70), respectively. Yet, the associations attenuated when adjusting for several covariates, including frequency of participation in sport activities in adolescence.

In addition to the quantity of sport activities, I also considered the quality (i.e., the type of sport activities) and calculated mean ltMETs and standard deviations for all possible subcategory (endurance, power, games, other sports) combinations. The full results are presented in Table 3 of Article 1. In the whole sample including inactive individuals, the mean ltMET values in adulthood were 4.36 MET-h/d (SD 3.56) for males and 3.96 MET-h/d (SD 3.44) for females. Twin individuals who had participated in sport activities covering all four subcategories or just the first three subcategories (endurance, power, and games) had the highest ltMET values in adulthood, in both males (5.18 MET-h/d and 5.05 MET-h/d, respectively) and females (4.95 MET-h/d and 5.14 MET-h/d, respectively). Among females, those who had not participated in endurance sport activities in adolescence seemed to have on average lower ltMET values in adulthood (3.11–3.82 MET-h/d), with the exception of those who only participated in power sports (4.23 MET-h/d). For males participating in only one category of sport activities, games (4.46 MET-h/d) and other sports (4.81 MET-h/d) related to higher than average ltMET values.

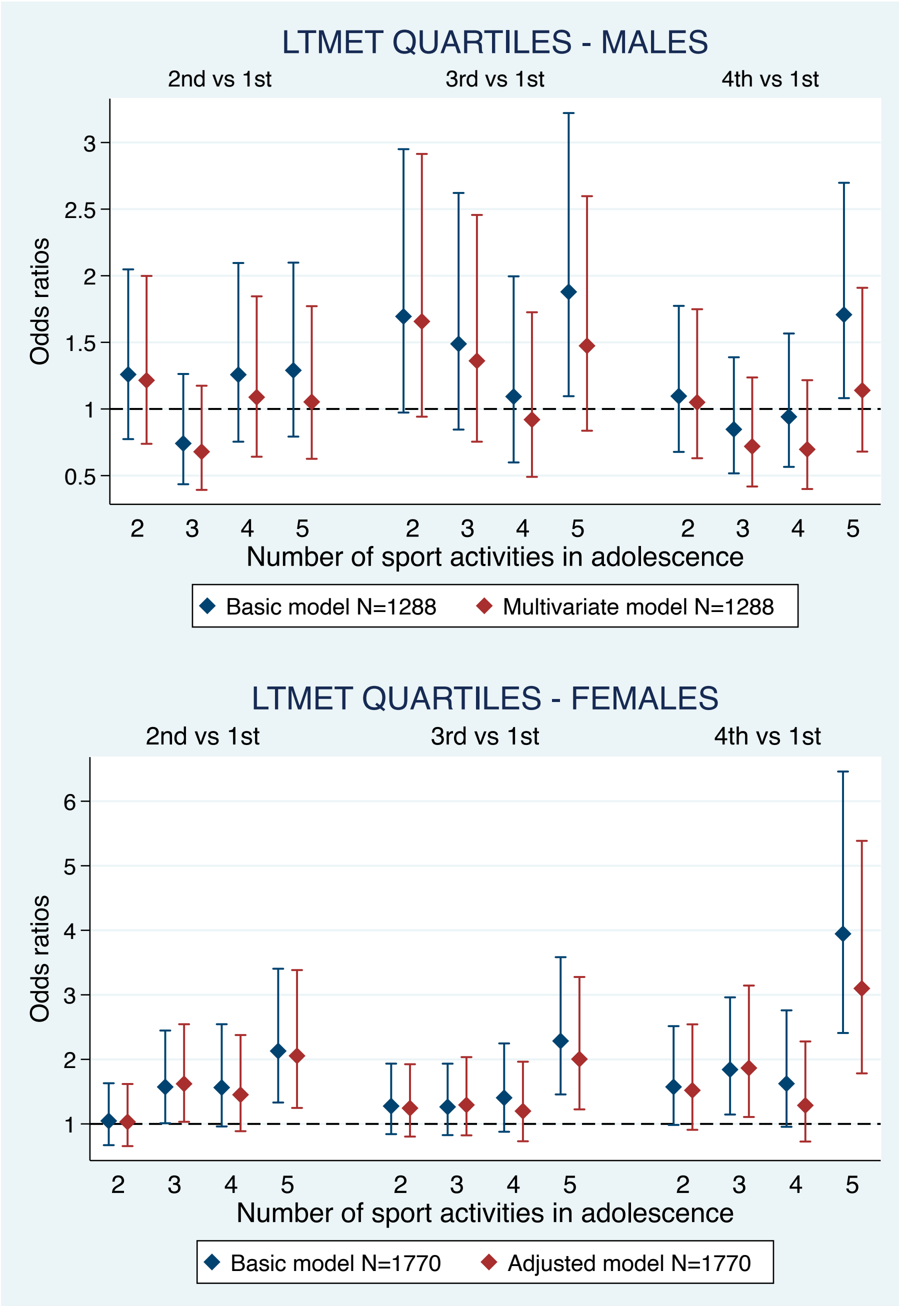

Figure 7 The results of the individual-based logistic regression analysis comparing participation in one vs several sport activities and membership in the more active vs the least active ltMET quartiles by sex. ltMET, leisure-time metabolic equivalent of task.

Basic model adjusted for age in adulthood
Multivariate model adjusted for leisure-time physical activity level in adolescence, age, general health, education level, work activity level, ever/never smoking, having children, and current pregnancy in adulthood

The within-pair analyses included only 23 baseline and outcome – discordant twin pairs (4 MZ and 19 DZ). The conditional logistic regression analyses were first conducted for all 23 pairs and then separately for MZ and DZ pairs, and finally separately for same-sex twin pairs (7 male pairs, 5 female pairs). The results are presented in Table 4. The sample size was small for discordant-pair analyses and no significant associations were detected. Thus, the results of the individual-based analyses were not replicated.

Table 4 The results of individual-based and within-pair logistic regression analyses comparing participation in one vs several sport activities and membership in the highest vs the lowest ltMET quartile.

	Membership in the highest vs lowest ltMET quartile		
Sample	**n**	**OR**	**95% CI**
Individuals[a]			
- **Both sex**	1842	1.43**	1.10-1.85
- **Males**	835	1.07	0.74-1.54
- **Females**	1007	1.94**	1.34-2.83
Double discordant twin pairs[b]			
- **DZ & MZ pairs**	23	1.28	0.54-3.05
- **DZ pairs**	19	1.07	0.41-2.79
- **MZ pairs**	4	3.00	0.31-28.84
- **Male-male pairs**	7	2.50	0.49-12.89
- **Female-female pairs**	5	0.25	0.03-2.24

ltMET, leisure-time metabolic equivalent of task; OR, odds ratio; CI, confidence interval; MZ, monozygotic; DZ, dizygotic

[a] Logistic regression model adjusted for sex

[b] Conditional logistic regression model adjusted for sex

**p<0.01

5.2 DIVERSITY OF SPORT ACTIVITIES AND SPINAL PAIN

In study II, I conducted both cross-sectional and longitudinal multinomial logistic regression analyses among twin individuals to determine whether the number of sport activities in adolescence or adulthood is associated with LBP or NSP in adulthood. In both basic (n=3201) and multivariate (n=3073) cross-sectional analysis, twin individuals participating in five or more sport activities in adulthood had significantly less weekly LBP (OR 0.63, 95% CI 0.43–0.90), but no less monthly LBP (Figure 8). A similar association was detected in the basic model (n=3207) for weekly NSP (OR 0.61, 95% CI 0.45–0.82), but the association attenuated in the multivariate analyses (n=3092). When I considered the quantity of sport activities as a float variable instead of categorization, every increase in the quantity was associated with less weekly LBP (OR 0.84, 95% CI 0.78–0.90) and less weekly NSP (OR 0.86, 95% CI 0.80–0.91) (Table 5), in analyses adjusted for age and sex.

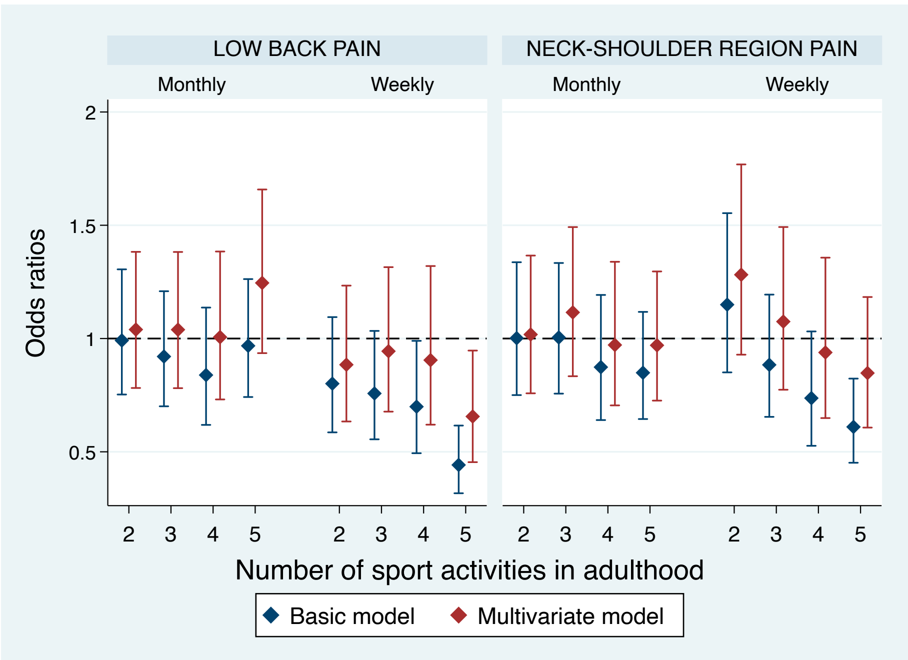

Figure 8 The results of the cross-sectional individual-based logistic regression analysis comparing participation in one vs several sport activities in adulthood and prevalence of monthly or weekly vs never/seldom low back and neck–shoulder region pain in adulthood.

Basic model adjusted for age and sex
Multivariate model adjusted for age, sex, mental health, sleep problems, leisure-time physical activity level, education level, work activity level, smoking*, body mass index*
*only for low back pain

In longitudinal analyses, the estimates remained in the same direction but no significant associations were found between the number of sport activities participated in in adolescence and spinal pain in adulthood (Figure 9). The multivariate models for LBP (n=2852) and NSP (n=2861) controlled for several covariates, including spinal pain at baseline.

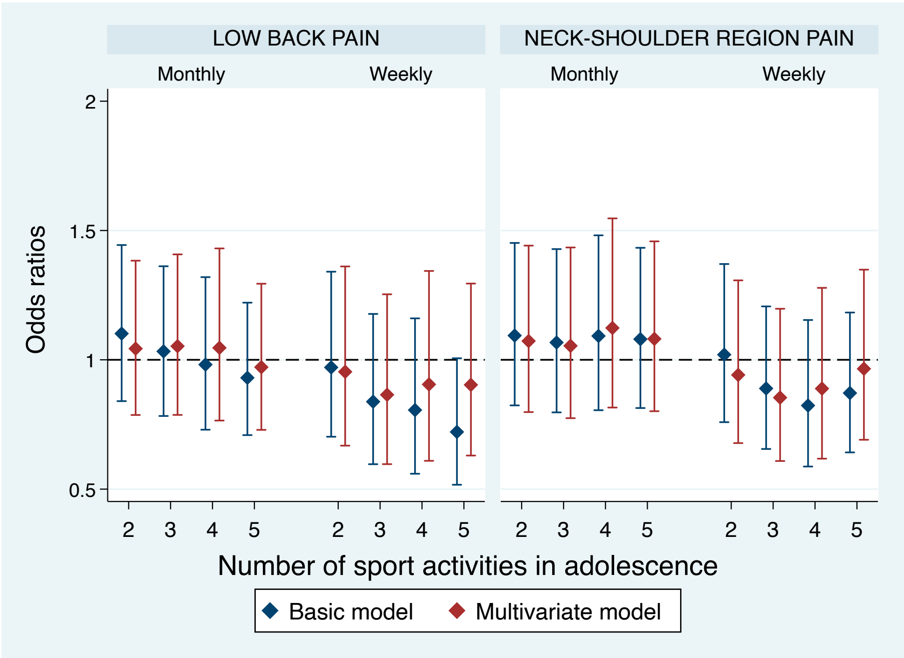

Figure 9 The results of the longitudinal individual-based logistic regression analysis comparing participation in one vs several sport activities in adolescence and prevalence of monthly or weekly vs never/seldom low back and neck–shoulder region pain in adulthood.

Basic model adjusted for age and sex
Multivariate model adjusted for spinal pain at age 16, age, mental health, sleep problems, leisure-time physical activity level, education level, work activity level, and smoking status* in adulthood
*only for low back pain

Additional sensitivity analyses included cross-sectional analyses among inactive individuals, among those who were excluded due to chronic illness or disability reported in adulthood, and among very active individuals achieving 11 or higher ltMET-h/day. The results were consistent between the chosen sample and the sample including inactive individuals as presented in Appendix C of Study II. Individuals who were excluded due to chronic illness or disability reported more weekly LBP and NSP but had similar sex distributions, equal LTPA levels and similar mean number of sport activities participated in when compared to the studied sample. No significant associations were detected among the small sample of very active individuals.

Longitudinal sensitivity analyses were conducted to control for potential reverse causality (i.e., the possibility that spinal pain hinders participation in sport activities). No significant associations were detected between baseline spinal pain symptoms and the number of sport activities participated in during adolescence or adulthood. Yet, weekly LBP and/or NSP at baseline had a significant association with weekly LBP (OR 2.92, 95% CI 2.31–3.70), and weekly NSP (OR 3.23, 95% CI 2.54–4.10) in adulthood.

Cross-sectional within-pair analyses, using a fixed effect multinomial logistic regression model, aimed to control for potential unmeasured familial factors underlying the association between the number of sport activities and spinal pain. Table 5 presents the ORs only for weekly LBP and NSP compared to never or seldom pain per increase of one sport activity participated in. Among MZ and DZ twin pairs discordant for LBP, the associations between participation in a higher number of sport activities and less weekly LBP were similar to individual-based results but non-significant. Instead, the significant association between the higher numbers of sport activities and less NSP was detected both among individuals (OR 0.86, 95% CI 0.80–0.91) and within MZ and DZ twin pairs discordant for NSP (OR 0.83, 95% CI 0.71–0.98). The significant association remained among discordant DZ pairs (OR 0.75, 95% CI 0.62–0.92), but attenuated among MZ pairs.

Table 5 The results of cross-sectional individual-based and within-pair logistic regression analyses comparing participation in one vs several sport activities and prevalence of weekly vs never/seldom low back pain in adulthood.

Sample	**Low back pain weekly vs never/seldom**			**Neck–shoulder region pain weekly vs never/seldom**		
	n	OR	95% CI	n	OR	95% CI
Individuals[a]	3201	0.84***	0.78-0.90	3207	0.86***	0.80-0.91
DZ & MZ pairs[b]	507	0.95	0.81-1.11	579	0.83*	0.71-0.98
DZ pairs[b]	336	0.99	0.81-1.20	376	0.75**	0.62-0.92
MZ pairs[b]	171	0.88	0.65-1.20	203	1.02	0.78-1.33

Modified from Kaartinen et al. 2019 (Study II)
OR, odds ratio; CI, confidence interval; MZ, monozygotic; DZ, dizygotic
[a] Logistic regression model adjusted for sex
[b] Conditional logistic regression model adjusted for sex
*p<0.05, **p<0.01, ***p<0.001

In Study III, I further investigated the cross-sectional associations between the quantity and quality of sport activities and the type of LBP with logistic regression analyses. As previously described in descriptive results, males reported significantly more non-radiating LBP, whereas females reported significantly more radiating LBP. Thus, all analyses were first run stratified by sex but further pooled together when no sex interaction was detected.

A higher quantity of sport activities seemed to be associated with less radiating LBP in both sexes (Figure 10) and less non-radiating LBP in males (Figure 11). In the basic model adjusting for age and sex (n=1269), it seemed that participation in 3, 4, or at least 5 sport activities was associated with less radiating LBP, with ORs of 0.57 (95% CI 0.38–0.84), 0.61 (0.39–0.95), and 0.46 (0.30–0.69), respectively. Similarly, participation in 3 or at least 5 sport activities had significant associations with less non-radiating LBP in the basic model (n=1251), with ORs of 0.58 (95% CI 0.38–0.88) and OR 0.66 (0.44–0.99), respectively. In the multivariate models for radiating (n=1206) and non-radiating (n=1200) LBP, all ORs remained below 1.0, but no significant associations were detected when sexes were pooled (Figure 10) or analyzed separately (Figure 11).

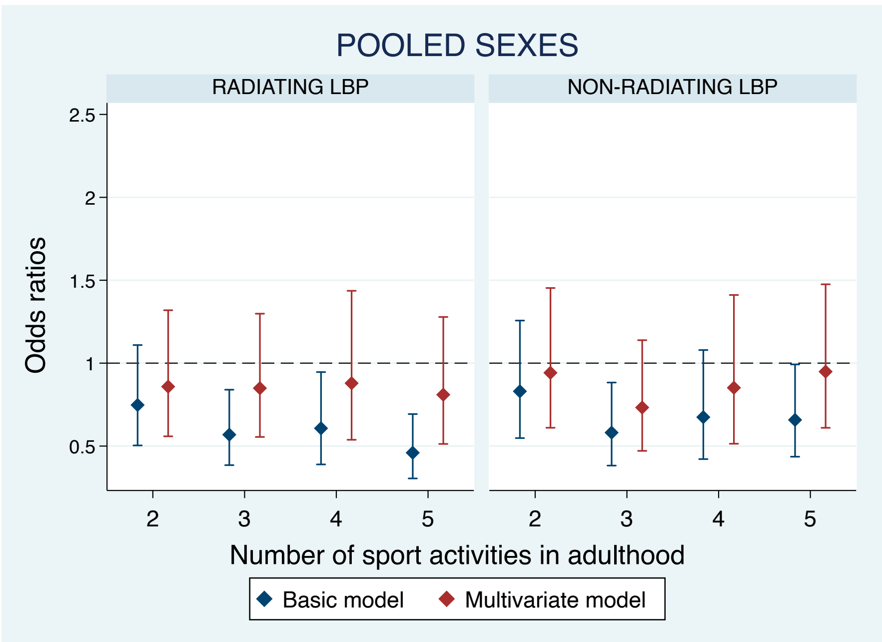

Figure 10 The results of cross-sectional individual-based logistic regression analyses comparing participation in one vs several sport activities and occurrence of radiating or non-radiating LBP vs no history of LBP lasting over one day in adulthood. LBP, low back pain.

Modified from Kaartinen et al. 2019 (Study III)
Basic model adjusted for age and sex
Multivariate model adjusted for age, sex, general health, mental health, sleep problems, leisure-time physical activity level, education level, work activity level, smoking status, body mass index

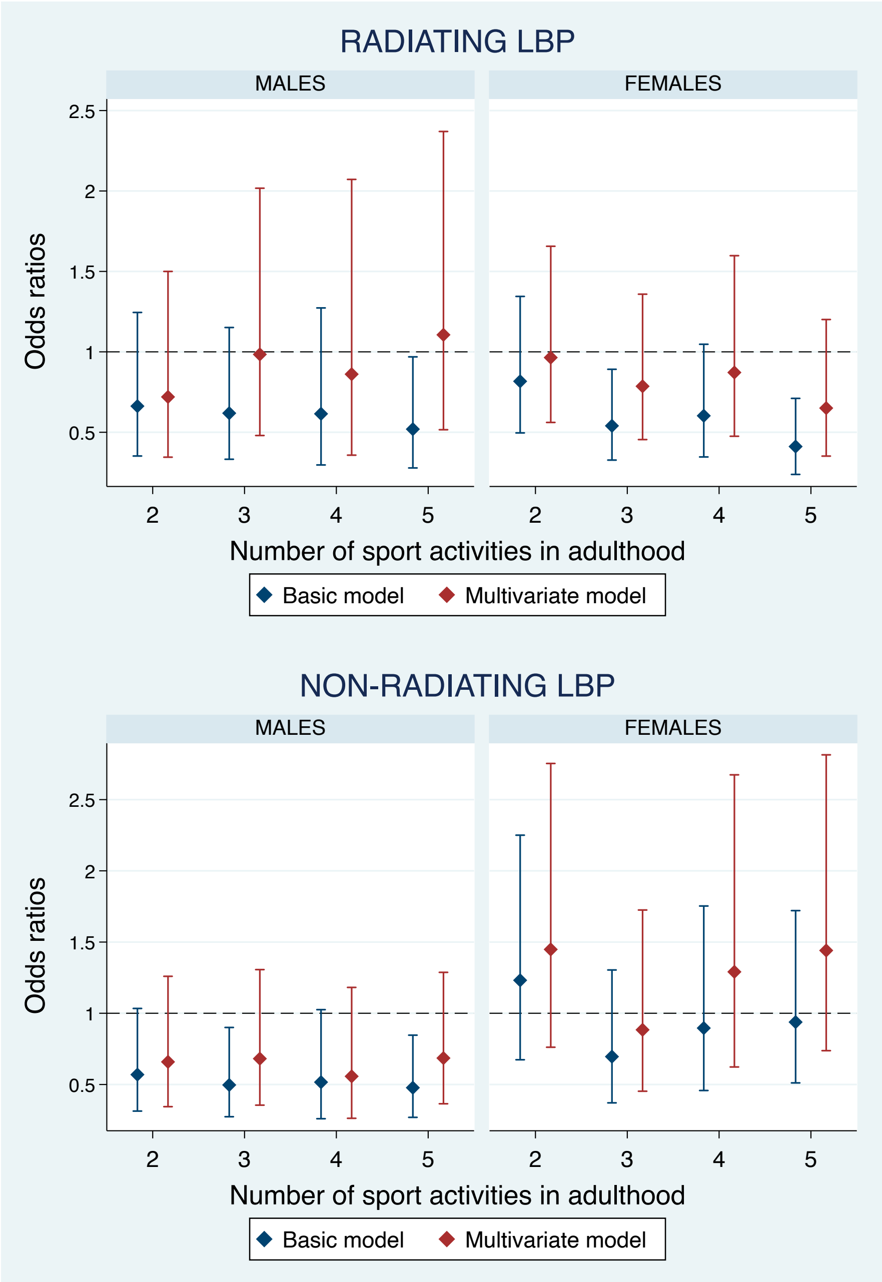

Figure 11 The results of cross-sectional individual-based logistic regression analyses comparing participation in one vs several sport activities and occurrence of radiating or non-radiating LBP vs no history of LBP lasting over one day in adulthood by sex. LBP, low back pain.

Basic model adjusted for age
Multivariate model adjusted for age, sex, general health, mental health, sleep problems, leisure-time physical activity level, education level, work activity level, smoking status, body mass index

In the analyses regarding type of sport activities and adjusted for sex and participation in all other types of sport activities, endurance sport activities were associated with both less radiating (n=1269) and non-radiating (n=1251) LBP (Figure 12). Participation in strength sports and body care activities was only associated with less radiating LBP. In further sport-specific analyses, participation in running and cycling in particular showed associations with less radiating and non-radiating LBP in analyses pooled for sex (full results are presented in the original publication of Study III).

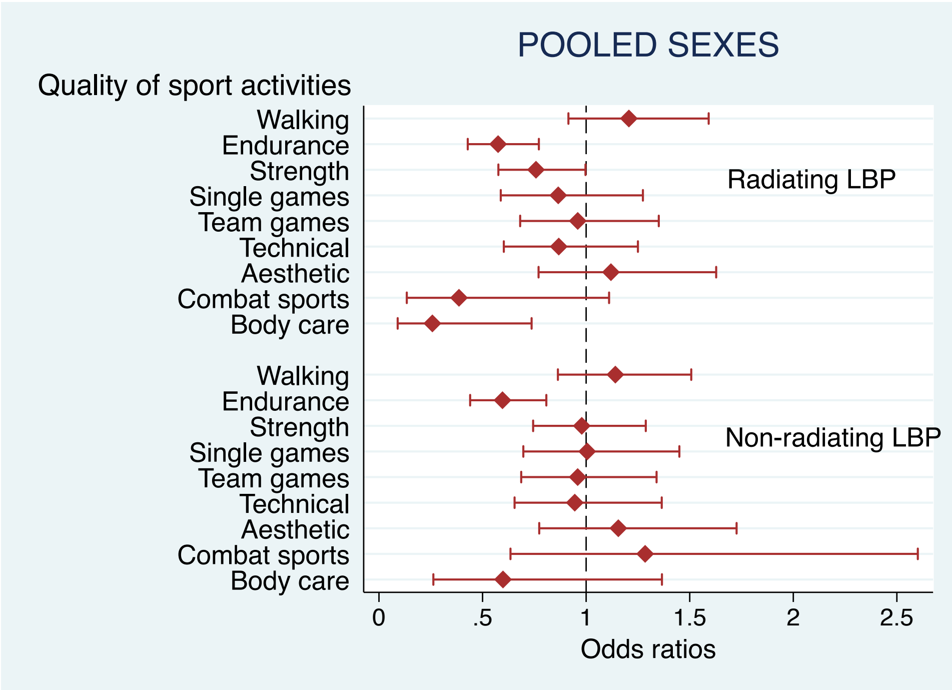

Figure 12 The results of cross-sectional individual-based multinomial regression analyses comparing participation in one vs several sport activities and occurrence of radiating or non-radiating LBP vs no history of LBP lasting over one day in adulthood, adjusted for sex and participation in other types of sport activities. LBP, low back pain.

6 DISCUSSION

6.1 SUMMARY OF MAIN FINDINGS

The findings of this thesis did not confirm but partially substantiated support for my hypothesis that participation in a diversity of sport activities may associate with higher LTPA levels and less spinal pains in adulthood when compared to a single sport participation. However, the first association may concern only females and the latter seemed to attenuate when all confounders were included. All three studies indicated that participation in five or more sport activities is required to reach the potential positive outcomes. In addition to the quantity, the quality of sport activities showed some significant associations with LTPA level in longitudinal design and type of LBP in cross-sectional design.

Study I confirmed that the number of sport activities participated in during adolescence is associated with higher ltMET levels (i.e., more weekly LTPA in adulthood), but only among females. This association was independent of the overall frequency of LTPA in adolescence. Participation in three types of sport activities (endurance, power, games, and/or others) in adolescence, however, seemed to result in higher ltMET levels in adulthood among both males and females in an unadjusted cross-tabulation. The within-pair analyses, though limited by the number of discordant twin pairs, indicated that familial factors may influence the association between number of sport activities in adolescence and LTPA level in adulthood.

Study II showed that in the cross-sectional design participation in several sport activities in adulthood, indepedent of the level of LTPA, is associated with less weekly LBP but not with less NSP in adulthood. In the longitudinal design adjusted for baseline pain, a similar, but non-significant, trend existed between the number of sport activities in adolescence and weekly LBP in adulthood. Cross-sectional within-pair analyses indicated that familial factors may influence the association between the number of sport activities and frequency of NSP in adulthood.

Study III detected that participation in several sport activities in adulthood is associated with both less radiating and non-radiating LBP (lasting over one day) in age- and sex-adjusted analyses. However, the associations attenuated when adjusting for several confounders. Regarding the quality of sport activities, participation in endurance sports seemed to be associated with both less radiating and non-radiating LBP in analyses pooled across sex and adjusted for participation in other types of sport activities. Endurance sports in particular showed associations with less radiating and non-radiating LBP among both males and females.

6.2 DIVERSITY OF SPORT ACTIVITIES AND LEISURE-TIME PHYSICAL ACTIVITY

The present results are consistent with previous longitudinal findings that participation in several adolescent sport activities, independent of the specific type of activity, is moderately associated with adult LTPA level (Jose et al. 2011; Kjonniksen et al. 2008), including active commuting to work (Cleland et al. 2012). In addition, some of the previous longitudinal studies have detected that participation in specific types or several different types of sport activities is associated with LTPA level in adulthood (Belanger et al. 2015; Engström 2008; Tammelin et al. 2003). The association between several different types of sport activities in late adolescence and higher LTPA levels in adulthood was supported by the current results. The longitudinal studies concentrating on adolescence have systematically indicated a positive association between participation in several sport activities and maintenance of higher LTPA levels at the edge of adulthood (age 18) (Aarnio et al. 2002; Aaron et al. 2002; Dovey et al. 1998; Robertson-Wilson et al. 2003). A similar association has also been found in an over 20-year follow-up of adults (Borodulin et al. 2012). The results of study I provide further support for the association between participation in several sport activities (independent of the frequency of LTPA) in late adolescence and LTPA level later in adulthood.

The present findings indicated that participation in 5 or more sport activities compared to participation in only one sport activity is required to reach the higher level of LTPA in adulthood. In contrast, previous Australian and Swedish studies have shown that participation in 3 or more sports compared to less than 3 sports is positively associated with LTPA in adulthood (Engström 2008; Jose et al. 2011). However, the present results from the basic model (adjusted only for age) also indicated that participation in 3 or more sport activities may be associated with higher levels of LTPA in adulthood among females. The Norwegian follow-up study reported no specific quantity, yet mean numbers of sport activities participated in in adolescence were 7.5 for males and 5.7 for females, whereas in adulthood 4.0 for males and 3.5 for females, respectively. The retrospective study of Canadian girls reported a similar quantity of sport activities (3.5–5.5) from age 6 to 18 among girls who were considered active at the age of 18, but only 1 or 2 among girls who were inactive at the age of 18 (Robertson-Wilson et al. 2003). Part of the differences in longitudinal findings may be explained by different quantities of sport activities at baseline which may be due to different populations (country, high-school students vs population-based), the year of the study, and the questionnaire or interview items. One of the studies collected information on only 6 sport activities (Cleland et al. 2012), whereas another one used a multiple-choice question similar to the FinnTwin16 study (Kjonniksen et al. 2008). In the FinnTwin 16 study, the adulthood questionnaire included more sport activities compared to the adolescence questionnaire, which signals the emergence of new sport activities between the 1990s and 2010. The wider range of sport activities may also partly explain the similar mean numbers of sport activities participated in during adolescence and adulthood (Table 3) even though the level of LTPA and sport participation is known to decline in the transition from adolescence to adulthood (Lounassalo et al. 2019). The Scandinavian countries and Canada have rather similar climates and seasonal variation in sport activities, such as kayaking in summer and skiing in winter, but in Australia winter sports are probably less common. Thus, the average quantity of sport activities in countries with four distinct seasons may be higher due to the variation in weather. Furthermore, participation in a higher quantity of sport activities may be required to maintain similar LTPA levels throughout the year in countries with four seasons. Instead, the difference between Finnish (Study I) and Swedish (Engström 2008) findings on the quantity of adolescent sport activities required to reach higher adult LTPA levels may spring from the quality of sport activities. In the FinnTwin16 study sample, the reported sport activities may have been rather similar, such as jogging and orienteering or gymnastics and dance, both of which were considered as separate categories in the study by Engström (2008). In summary, participation in 5 or more sport activities may be required to increase LTPA levels later in life throughout changing seasons, as well as inclusion of dissimilar (i.e., a diversity of) sport activities.

Suprisingly, we found a significant association between the quantity of sport activities in adolescence and LTPA level in adulthood only among females. In contrast, previous studies have reported no similar sex-specific difference in the association, with exception of Kjonniksen et al. (2008) who reported a greater decrease in both the number of sport activities and LTPA levels among males. Many studies, however, have shown that males participate more frequently in LTPA and more often in vigorous sport activities (Aarnio et al. 2002; Caspersen et al. 2000; Hallal et al. 2012), as well as better maintain their physical activity level (Lounassalo et al. 2019; Telama 2009). Moreover, males more often report participation in team sports, whereas females more often report participation in individual activities (Aarnio et al. 2002; Aaron et al. 2002; Belanger et al. 2015; Tammelin et al. 2003). These sex differences in sport activity profiles can partly account for the detected sex differences in the association between the quantity of sport activities and LTPA level calculated as ltMET value. Males might reach an average of 3 ltMET-h/d playing soccer (7 METs/h) twice a week for 1.5 hours, whereas females engaged in, e.g., walking (4 METs/h) and pilates (3 METs/h) need to exercise 1.5 hours four times a week to reach the same MET value. In the FinnTwin16 sample, adult males had significantly higher ltMET values compared to females, yet the quantity of sport activities participated in was similar in both sexes. This provokes the idea that among women, LTPA levels are more dependent on participation in several sport activities.

Of note in the comparison of present and previous studies is the mean age of the sample in follow-up, which may also contribute to the sex differences. In most of the previous studies, individuals were younger at follow-up, yet in three studies individuals were approximately in their thirties (Cleland et al. 2012; Jose et al. 2011; Tammelin et al. 2003). Many life changes that are known to affect LTPA levels often occur in the transition from adolescence to adulthood and around age 30. These include transition to university, beginning a job, marriage, pregnancy, and having a child, many of which have at least traditionally influenced women more than men (Engberg et al. 2012). Even when family responsibilities are shared equally, pregnancy and having a child may change women's capability to engage in different sport activities. Thus, the diversity of experiences on sport activities earlier in life could help women especially to maintain their LTPA level during changes in life and in their own body.

In accordance with the Swedish study (Engström 2008), we also found that participation in at least three different types of sport activities in adolescence related to the highest LTPA levels in adulthood. Similar to findings of Tammelin et al. (2003) and Belanger et al. (2015), participation in endurance sports, including running, related to higher LTPA level in adulthood, yet mostly among females in the FinnTwin16 sample. Interestingly, in the present study, among individuals who participated in only one category of sport, females engaged in power sports and males engaged in games or other sports (including, e.g., combat sports and downhill skiing) had higher than average LTPA levels in adulthood. Among females, the results are based on a very small number of participants (n=5), whereas the results among males are consistent with earlier findings (Kjonniksen et al. 2008; Tammelin et al. 2003). Previously, Kjonniksen et al. (2008) found that sustained participation in ball games and downhill skiing is common among females. Results of Tammelin et al. (2003) suggested that males sustained participation in endurance activities, such as cross-country skiing and running, from adolescence to adulthood more often than females. Thus, both previous and present findings support the idea of Sallis et al. (1996) that running may have a special role as a transferable skill between different sport activities. Moreover, running and soccer are known to benefit aerobic fitness, postural balance and reduce adiposity, which may ease participation in different sport activities simultaneously or in the future (Oja et al. 2015).

A possible explanation for the distinct role of endurance activities, including walking and cycling, might be that active commuting was included in ltMET values. A Finnish study observed that sustained or increased active commuting from adolescence to adulthood is related to higher overall physical activity level in adulthood (Yang et al. 2013). In Nordic countries, walking or cycling to work is rather common and thus represents a notable part of LTPA behavior (Hallal et al. 2012). Particularly during the above-mentioned eventful years in early adulthood, active commuting may provide the most convenient way for regular LTPA. Another possible explanation for endurance sports being beneficial for LTPA levels later in life is the independent nature of participation. Running and walking are activities which can take place nearly everywhere and anytime, as well as have little requirements regarding equipment or motor skills (Rinne et al. 2007). Reviewed evidence also suggests that in aiming to enhance LTPA levels globally adolescents should increase active transportation to and from school, independent mobility and "free-range activities" without adult supervision (Condello et al. 2017).

Previous and present results cover the range from childhood through adolescence to the mid-thirties, whereas evidence on participation in a diversity of sport activities during adulthood is scarce. Both the findings of Engström et al. (2008) and Borodulin et al. (2012) support the idea that participation in different types of activities is beneficial still in later adulthood. The breadth of sport experiences in adolescence showed significant associations with LTPA among Swedish individuals in their fifties (Engström 2008). In a 22-year follow-up of Finnish adults, aged 30 to 80 years at baseline, participation in 3 or more different sport activities showed the strongest association with being physically active in leisure time at the follow-up (Borodulin et al. 2012). Further, participation in both walking and weight-bearing exercise, particularly from midlife, seems to be related to higher physical activity levels in later life (Elhakeem et al. 2017). Thus, participation in a diversity of sport activities in adulthood still seems beneficial in terms of LTPA levels later in life.

Finally, the within-pair analyses showed that familial factors may confound the association between the quantity of sport activities in adolescence and LTPA levels in adulthood. However, the sample size was rather small and accordingly the analyses lacked statistical power. The results are still consistent with the evidence that LTPA behavior is significantly influenced by genetic factors (Lightfoot et al. 2018). In the FinnTwin16 sample, the heritability of LTPA has been estimated to be around 43–52% during adolescence and declines to ~30% in young adulthood (age 24) (Aaltonen et al. 2014). These estimates are in the range of the international estimations which show that the role of familial factors, including genetic influences, decreases, whereas the role of environmental influences increases in the transition from adolescence to adulthood (Lightfoot et al. 2018). This is interesting since familial and environmental factors influencing a behavior, such as LTPA, may also be seen as a modifiable and non-modifiable component. In the aim to produce efficient strategies to enhance LTPA behavior, it is very valuable to know to what extent the environmental influences might affect it. If the behavior is strongly influenced by familial factors, including genes, it may be more difficult to change it with modifications in the environment. Thus, physical activity recommendations need to take this into account in the aim to create cost-effective physical activity interventions. Currently, as far as we know, heritability estimates on the diversity of sport activities are lacking.

In summary, this research provided further support for previous findings on the beneficial effects of participation in a diverse quantity and quality of sport activities in adolescence on LTPA level in adulthood, among females. The new information was that the association may be confounded by familial factors, which requires confirmation in future studies.

6.3 DIVERSITY OF SPORT ACTIVITIES AND SPINAL PAIN

This thesis focused on spinal pain in adulthood and mainly found cross-sectional accociations between a diversity of sport activities and LBP. The cross-sectional results for NSP showed no significant associations, but detected potential confounding by familial factors. According to these results, we further studied the association between a diversity of sport activities and the different types of LBP, radiating and non-radiating LBP. Similar to the literature review, the discussion considers first LBP and then NSP due to the varying quality and quantity of evidence.

6.3.1 LOW BACK PAIN

The present findings are well-supported by the accumulated evidence on the association between regular participation in LTPA and less non-specific and radiating LBP (Alzahrani et al. 2019; Shiri et al. 2016; Shiri and Falah-Hassani 2017). None of the population-based studies, however, have explored if the quantity of sport activities is related to LBP. The results of Study II showed that those who participated in 5 or more sport activities, compared to single sport participants, had less weekly but no less monthly LBP in adulthood, independent of the level of LTPA. These results are consistent with previous findings primarily between LTPA and chronic (i.e., continuous) LBP (Shiri and Falah-Hassani 2017). One explanation for the difference between monthly and weekly LBP is that participation in vigorous sport activities might provoke occasional, such as monthly LBP (Heneweer et al. 2011). Acute LBP is often caused by physical factors and is also a common complaint among athletes who, however, seem to have lifetime prevalence of LBP similar to non-athletes (Farahbakhsh et al. 2018; Videman et al. 1995; Villavicencio et al. 2006). The occasional non-specific LBP among adults is rarely a sign of severe pathology but a common symptom typically leveling off in days or weeks (Daniels et al. 2011; Maher et al. 2017). The difference between monthly and weekly LBP may also be partly explained by the role of psychological factors and LBP-related disability. Vlayen et al. originally formulated the fear-avoidance model to describe the development of acute to chronic back pain, and later evidence has supported the role of psychological and cognitive factors, including structural brain differences, in the development of chronic pain and disability (Crombez et al. 2012; Kregel et al. 2015; Linton 2000; Vlaeyen et al. 1995). Participation in several sport activities could help to maintain LTPA despite weekly pain and potential perceived disability. Yet, why participation in 5 or more sport activities seemed to be required to reduce the odds for weekly LBP is probably due to similar reasons as those discussed in section 6.2. In the present sample of individuals who engaged in LTPA at least monthly, participation in 5 or more sport activities can raise the likelihood to sustain LTPA throughout changing seasons and more likely includes different types of sport activities, which may reduce the risk of weekly LBP.

No prior studies, as far as we are aware of, have examined the quantity or quality of sport activities in relation to radiating or non-radiating LBP in adulthood. Similar to non-specific LBP, radiating LBP has also shown a U-shaped relationship with LTPA, which indicates that both low and high intensity or frequency of LTPA may be a predisposing factor (Shiri et al. 2010a). The present results on the association between several sport activities and less radiating or non-radiating LBP, which attenuated when adjusting for confounders, did not directly support or oppose the sparse previous evidence. The findings of Study II and III regarding quantity of sport activities and LBP, however, are consistent, though the restricted sample size in Study III might have affected the attenuation of results in multivariate analysis.
The attenuation of association between quantity of sport activities and different types of LBP when adjusting for general and mental health, sleep problems, smoking, BMI, LTPA level, and physical demands at work, also corroborates the known multifactorial nature of LBP (J. Hartvigsen et al. 2018). Of note, the results of Study II were also adjusted for LTPA level, which indicates that participation in several sport activities may have an independent effect on non-specific LBP.

The present population-based findings are rather consistent with prior evidence on the quality of sport activities, and non-specific LBP is mainly derived from adolescent and athlete samples. Results of Study III are in accordance with observations that participation in endurance sports, such as running and cycling, is related to less LBP (Auvinen et al. 2008; Farahbakhsh et al. 2018; Fett et al. 2017; Foss et al. 2012; Guddal et al. 2017; Trompeter et al. 2017; Videman et al. 1995). Yet, current and previous population-based evidence on rowing and cross-country skiing (Auvinen et al. 2008; Guddal et al. 2017) is inconsistent with athlete studies which have reported higher prevalence of LBP in rowers and cross-country skiers (Foss et al. 2012; Trompeter et al. 2017). This could be partly due to higher training loads among athletes throughout the year, whereas in the general population rowing and cross-country skiing are very season-specific sports. Only Villavicencio et al. (2006) have reported separate estimates for lifetime prevalence of non-specific (67.8%) and radiating LBP (28.7%) among triathletes, which were in the range of population-level estimates, further supporting the present findings (Hoy et al. 2012; Konstantinou and Dunn 2008). In contrast to endurance sport activities and the present results, LBP has seemed to be a common complaint in team games (e.g., ice hockey, basketball), combat sports, and other activities with a high risk of trauma (e.g., downhill skiing), particularly among young athletes (Auvinen et al. 2008; Balagué et al. 1999;

Farahbakhsh et al. 2018; Guddal et al. 2017; Jonasson et al. 2011; Noormohammadpour et al. 2016; Sato et al. 2011; Triki et al. 2015). Notably, traumatic LBP is common among young athletes, but primary causes of LBP in adult athlete populations are mechanics and osteoarthritis (Daniels et al. 2011). Accordingly, adolescent athletes predisposed to repetitive extension, flexion and rotation of the spine are more prone to LBP (Daniels et al. 2011; Purcell and Micheli 2009), whereas among former and adult athletes no such association has been detected (Fett et al. 2017; Foss et al. 2012). Thus, the discrepancies between prior and present results could be attributed to different study populations. In addition to dissimilar causes of LBP between adolescent and adult populations, the physical demands in work life tend to diverge from those of at least those in primary school. In contrast, the work of an athlete may consist of only training, which makes a marked difference in the training loads between general and athlete populations. This is further supported with studies that have found signs of greater disc degeneration among athletes compared to the general population, with the exception of competitive runners and shooters (Ong et al. 2003; Videman et al. 1995). The degenerative changes detected with imaging, however, are not evidently related to LBP (J. Hartvigsen et al. 2018; Videman et al. 1995). Overall, the most established risk factor for LBP among adolescent, adult, and athlete populations is previous LBP (Auvinen et al. 2008; Foss et al. 2012; J. Hartvigsen et al. 2018; Heneweer et al. 2011), whereas the effect of high training loads may be more dependent on the quality of sport activity participated in.

The familial factors showed no confounding in the cross-sectional analyses between quantity of sport activities and frequency of non-specific LBP. This is somewhat contrary to findings among older (mean age 57) Spanish twins, indicating that familial factors confound the association between recent LBP and adherence to physical activity guidelines (Zadro et al. 2017). Both LBP and LTPA measures, however, were different in the study of Zadro et al. (2017) compared to FinnTwin16: 1) recent LBP within 4 weeks versus monthly or weekly LBP during the past six months and 2) meeting the WHO physical activity guideline versus quantity of sport activities, respectively. Previous twin studies on LBP have found a range of heritability estimates from 21% to 67% and suggested that the contribution of genetic factors is higher in chronic and disabling LBP compared to acute and less disabling LBP (Ferreira et al. 2013). The heritability of LTPA is in a similar range but no estimates on the heritability of diverse sport participation exists (Lightfoot et al. 2018). Thus, explanations for the contradiction between the present findings and prior results of Zadro et al. could be that familial factors influencing the quantity of sport activities may be fewer or dissimilar from the ones influencing LBP. Since no confounding by familial factors in the association of sport activities and LBP appeared in Study II, no within-pair analyses took place in Study III, which concentrated on subtypes of LBP in a restricted sample.

Interestingly, the results of Zadro et al. also suggested that recent LBP decreases the likelihood to reach physical activity guidelines, which is an opposite direction of association than hypothesized in this thesis. A short-term reduction in LTPA levels after LBP onset is common but opposite to the current guidelines of non-specific LBP treatment advising to sustain physical activity ("Low Back Pain: Current Care Guidelines" 2017). Present longitudinal results, however, indicated that participation in several sport activities in adolescence is related to less weekly LBP in adulthood, although statistical significance was not achieved. This does not suggest preventive, protective or any other causal association but indicates that more longitudinal studies should be conducted to clarify the potential association. The current follow-up of 17 years was rather long and thus, future studies with more frequent follow-up measurements would be informative. In support of present results, the recent review of observational studies found an inverse relationship between moderate compared to low level LTPA and less LBP in both cross-sectional and longitudinal study designs (Alzahrani et al. 2019). A moderate level was from about 12 to 19 MET-hours per week, which equals less than 3 MET-hours per day, i.e., less than an hour of walking. This evidence supports the idea that regular participation in non-vigorous activities may reduce the risk of LBP. Consistently, evidence among chronic LBP patients suggests that moderate-level sport activities including walking, cycling and swimming might help to control pain and maintain fitness (Ribaud et al. 2013). Similar evidence exists on yoga and Pilates (Wieland et al. 2017; Yamato et al. 2016) and the present cross-sectional results consistently indicated less radiating and non-radiating LBP among individuals who participated in body care activities. Suprisingly, the results showed an inverse, yet non-significant, association for those who engaged in walking or swimming. This inverse cross-sectional result could indicate both the preferences of individuals with LBP, as well as advice given to them by health professionals.

In summary, this research increased the knowledge on the associations of the quantity and quality of sport activities with different types of LBP in adulthood. The results suggest that the quantity of sport activities may play a role besides LTPA level in the prevalence of non-specific LBP. In contrast, the quality of sport activities might be more strongly related to over one day episodes of radiating and non-radiating LBP.

6.3.2 NECK–SHOULDER REGION PAIN

No previous studies have explored both cross-sectional and longitudinal associations between the quantity of sport activities and frequency of NSP in adulthood. Only one cross-sectional Finnish study among adolescents has detected less neck pain in boys who participated in several different sport activities compared to peers with less diversified sport participation (Auvinen et al. 2008). In cross-sectional individual-based analyses adjusted only for age and sex, we also found significant association between participation in 5 or more sport activities and less weekly NSP in adulthood. When the quantity of sport activities was a float variable, every increase in the quantity of sport activities related to less weekly NSP. This supported the trend seen in the category-wise estimates and further indicated that some of the categories might have lacked power. However, the inclusion of multiple known confounders in the analyses attenuated the association between several sport activities and less weekly NSP. This might depict the multifactorial nature of NSP. From the included confounders, especially poor psychological health, sleeping problems, and physical demands at work can have a greater influence on the frequency of NSP than LTPA (Haldeman et al. 2010; Hogg-Johnson et al. 2008). In addition, the attenuated estimates after including the level of LTPA as a confounder may imply that the association is partly dependent on the level of LTPA. Moreover, the within-pair analyses suggested that the cross-sectional association between the quantity of sport activities and NSP is confounded by familial factors in the FinnTwin16 sample. In a sample of Finnish preadolescents, the heritability estimate for neck pain has been as high as 68% (Stahl et al. 2013), whereas for Danish adults the estimates range from 34% in women to 52% in men (Fejer et al. 2006b). Thus, it seems possible that present results can be confounded by genetic influences in the studied population and accordingly, further studies in different populations are required to clarify the present findings.

The lack of longitudinal association between quantity of sport activities in adolescence and frequency of NSP in adulthood was not that suprising in light of the scant previous evidence. Instead of prevention, most of the research has concentrated on the treatment of neck pain with different types of exercises and found strong enough evidence to recommend exercise therapies (Jensen and Harms-Ringdahl 2007; Sterling et al. 2019). The Swedish cohort studies including large population-based samples of adults have mostly indicated that participation in LTPA and healthy lifestyle behaviors (including physical activity, smoking, alcohol intake, and diet) could protect against chronic or prolonged troublesome neck pain (Palmlof et al. 2016; Skillgate et al. 2017). The beneficial association between LTPA and chronic neck pain also only considered in previously pain-free individuals (Palmlof et al. 2016). Yet, according to some evidence, neck pain may have its origin already in preadolescence (El-Metwally et al. 2004; Siivola et al. 2004), which suggests that follow-up should be started even earlier than in FinnTwin16. In addition, more frequent measurements would be required, since the present follow-up of 17 years could have been too long. The only other longitudinal study ranging from adolescence to adulthood considered the quality rather than quantity of sport activities and found that good flexibility in boys and good endurance strength in girls might reduce the risk of neck tension in adulthood (Mikkelsson et al. 2006). Further, the studies among athletes generally suggest more traumatic NSP in contact sports and a similar or lower prevalence of NSP in endurance sports (Jonasson et al. 2011; Villavicencio et al. 2007), with the exception of cycling in which the riding position may predispose to neck pain (Auvinen et al. 2008; Deakon 2012; Weiss 1985).

In summary, to my knowledge, this research was the first to study the association between the quantity of sport activities, in adolescence and adulthood, and NSP in an adult population. The results showed no significant association, yet indicated that familial factors may be confounding the cross-sectional association. Overall, regarding the present and previous studies, it seems that NSP may be more related to quality than quantity of sport activities.

6.4 METHODOLOGICAL CONSIDERATIONS

Most of the strengths and limitations in the present studies are related to the FinnTwin16 study, including the questionnaire-based measures of the diversity of sport activities, LTPA and spinal pain.

6.4.1 PARTICIPANTS AND STUDY DESIGN

Overall, the FinnTwin16 study consitutes a large, population-based, and geographically representative cohort with good response rates (Kaidesoja et al. 2019; Kaprio et al. 2002). The age range in the cohort is narrow which makes the cohort rather homogeneous regarding environmental changes such as modifications in the Finnish school system and digitalization. The share of males and females is adequate, yet as is typical for questionnaire studies adult females are more responsive. In the within-pair analyses including only discordant twin pairs, however, the sample becomes more restricted and statistical power may be compromised which depicts the high similarity within a twin pair.

Twin individuals constitute a special study population with advantages and potential biases. In childhood and adolescence, twins are usually reared together and thus tend to share at least the family environment, but often also school and leisure-time activities. In addition, MZ twins share 100% of their segregating genes whereas DZ around 50%, which is similar to normal siblings. These similarities are required for within-pair analyses, but also constitute a potential bias in individual-based analyses due to correlated observations which were controlled for with robust estimators of variance. In addition to similarity within a twin pair, all twin individuals share distinct prenatal circumstances. Twin individuals are often born prematurely and with lower birthweight, which has been related to low LTPA levels later in life (Andersen et al. 2009). However, a recent Finnish study using objectively measured physical activity in young adulthood, found no differences between early or late preterm born individuals and full-term controls (Tikanmäki et al., 2016). Notably, low birthweight among twin individuals is more often due to physiological causes, i.e., lack of space in utero during the latter part of pregnancy, than among singletons (who may more often have suffered from placental or fetal disturbances). In the FinnTwin16 study, however, the physical activity patterns of adolescent twins were similar in comparison to singletons (Aarnio et al. 2002), and LTPA levels of adult twins were higher than on average in Finnish or global adult populations (Hallal et al. 2012; Koskinen et al. 2012). When it comes to prevalence of spinal pain, previous studies have reported no significant differences between twin individuals and singletons (Ferreira et al. 2013; Nielsen et al. 2012). Present estimates on the prevalence of monthly and weekly LBP and NSP combined were consistent with a study among the European working population (Farioli et al. 2014), as well as with the Finnish "Health 2011 survey" (Koskinen et al. 2012). Thus, the present findings based on the Finnish twin sample may rather well be generalized to the whole Finnish population.

In all three studies, exclusion criteria included twins who participated in LTPA less than once a month (i.e., inactive) in an aim to study the diversity of sport activities among individuals who somewhat regularly engage in LTPA and at least one sport activity. Evidently, this sample cannot be referred to as "physically active" or "active sample" since LTPA 1–2 times per month is inadequate to meet the current physical activity guidelines. Participation in only one sport activity, however, might relate to less frequent participation in LTPA among the general population. Thus, excluding those who engage in LTPA only 1–2 times per month would have reduced the size of the reference group in the analyses which supported using the broader criterion when exploring participation in a diversity of sport activities. Moreover, Finland is a country with four distinct seasons and many of the popular sport activities, such as cross-country skiing, are season-specific, which makes weekly participation difficult and might influence how individuals report their frequency of LTPA participation. To compensate for the broad range of LTPA levels, multivariate analyses incorporated the LTPA level as a confounder. In addition, sensitivity analyses also contained inactive individuals (Study I and II), and the results were consistent with the primary sample.

Other reasons for exclusion were being currently pregnant in adulthood (Study II and III) and chronic diseases or disabilities that hinder daily activities at baseline or in adulthood (Study I, II, III). In Study I, pregnancy was a confounder in the multivariate model since both the exposure and outcome described LTPA, which may decrease due to pregnancy but is not prohibited. In contrast, pregnancy often causes spinal pain and thus, in Studies II and III, it was more reasonable to exclude currently pregnant women. Further, the sensitivity analyses (Study II) detected no differences in LTPA levels or quantity of sport activities among individuals excluded due to chronic illness or disability in adulthood who, nevertheless, reported more spinal pain compared to the chosen study sample. Overall, the studied sample was carefully chosen and controlled for. The results may be generalized to healthy and at least the monthly LTPA-participating Finnish population.

In terms of study design, this thesis includes cross-sectional, longitudinal, and within-pair settings. In Study I, longitudinal and within-pair analyses were well-founded and informative since earlier evidence with shorter follow-up times existed. Accordingly, Study II exploring previously less studied associations, started with cross-sectional analyses and completed with longitudinal analyses including adjusting for baseline spinal pain and cross-sectionl within-pair analyses adjusting for unmeasured familial factors. Further, Study III included only cross-sectional analyses. Obviously, cross-sectional design is unable to identify the direction of the association and does not rule out reverse causality. Individuals, however, reported participation in sport activities and the frequency of spinal pain not only recently but during the past six months, which does not reduce the probability of reverse causality but may favor rather a semantic than episodic retrieval strategy (Robinson and Clore 2002). In the analyses of Study II, the estimates retained their direction in longitudinal analyses which were adjusted for baseline pain, supporting the hypothesized direction of association. In the sensitivity analysis, baseline pain (first wave) had no association with the number of sport activities in adolescence (second wave) or adulthood. Unfortunately, no information was available on spinal pains simultaneously with the number of sport activities during the second wave. An additional sensitivity analysis excluding individuals with spinal pain at baseline could have provided more valuable information since spinal pain is often a recurrent condition. The present results are unable to rule out that change in LTPA during the rather long follow-up is not a consequence of pain at baseline. Overall, the follow-up of 17 years was longer than would be ideal when investigating such fluctuating behavior and symptoms as LTPA and spinal pains. With more frequent follow-up surveys, it would have been possible to study trajectories of LTPA and spinal pain to gain more information on the potential temporal changes and the associations between them.

What comes to the within-pair analyses, Study I suffered from the small number of extremely discordant twin pairs in the conditional logistic regression analyses. Possibly, using the more recent fixed-effects multinomial logistic regression model (used in Study II), the statistical power would have been better. The choice of analyses, naturally, was based on the prevailing knowledge. In any case, the within-pair analyses in Studies I and II were the first of their kind, as far as we know, and thus provided new information.

In summary, the key strengths of the present studies are the longitudinal study designs with considerably low loss to follow-up, as well as the unique nature of the twin sample. The largest biases related to FinnTwin16 study sample have been accounted for, yet inclusion of the criterion “participation in LTPA at least once a month” may both cover up and cause a margin of error. The reduced sample size in within-pair analyses is a common problem which may be diminished with newer statistical methods. Based on current study designs, no causal relationships can be declared and further studies are recommended to use large population-based samples with more frequent measurements to replicate the findings.

6.4.2 MEASUREMENTS

This thesis is based on survey data and subjective measurements of both LTPA behavior and spinal pains. Self-reports are prone to response biases including under- and overreporting, false interpretations of questionnaire items and recall bias related to memory function. All these may have caused measurement error and confounded the results of this thesis. The validity and reliability of LTPA and spinal pain measures are well-studied in comparison to the main characteristic of this thesis, the diversity of sport activities.

The assessment of both the quantity and quality of sport activities was based on multiple-choice questions including several sport activities without sport-specific frequency and intensity of participation. Thus, weekly and occurring a few times a year participation in a sport activity were coded similarly, which reduces the accuracy of the measure. Additionally, the number of sport activities in the multiple-choice question was different in the second and fifth survey waves which might have reduced the internal consistency. This could also explain the surprisingly similar mean numbers of sport activities participated in during adolescence and adulthood. It is also noteworthy that the quantity of sport activities has increased from the 1990s to the 2010s, and the multiple-choice questions included the most popular prevailing sport activities in Finland. Moreover, information on participation in school sports was lacking, which might have restricted the possibility to capture the total diversity of sport activities in adolescence, but also provided a chance to concentrate solely on LTPA. Of note, there were only a few compulsory physical education classes in the academic or vocational secondary schools in 1992–96. Furthermore, my focus was on LTPA, which best describes voluntary physical activity behavior and can be better influenced on a population-level than physical activity at school or workplaces.

Ideally, I could have used the quantity of sport activities as a continouous variable, but it was statistically inappropriate due to the floor-effect consisting of a few participants reporting over 10 different sport activities. The categorization of the skewed quantity of sport activities, however, balanced the potential overreportation as the last category was 5 or more sport activities. Since the literature provided no threshold value for diverse sport participation regarding the quantity of participated sport activities (Table 2), I chose a statistically well-founded approach with 5 rather equally sized categories, even at the potential cost of some statistical power. In contrast, the quality-based groupings of sport activities utilized previously described approaches being different when exploring LTPA later in life (Aarnio et al. 2002) and spinal pain in adulthood (Guddal et al. 2017). In an aim to assess the diversity of sport activities, simultaneous exploration of both the quantity and quality of sport activities provided a broader description of the behavior and thus increased the validity of the diversity measurement.

In the analyses, LTPA level was also a categorical variable due to the skewed distribution of ltMET values. This is a common problem in the field and many researchers have chosen the categorization approach (Alzahrani et al. 2019). Similar to the quantity of sport activities, I used a statistical approach to divide individuals into equally sized ltMET quartiles to avoid the problem of an underpowered category. In support of the validity of the present categorization, it resulted in cut-off points similar to the WHO recommendation for weekly PA (equal to 1.5 MET-h/day) with the lowest ltMET quartile being close to that (1.53 ltMET-h/day for males and 1.49 MET-h/day for females) (World Health Organization 2010). Furthermore, although statistical power somewhat decreased with categorized variables, the present results depicted the clear threshold for the amount of sport activities in adolescence required to positively affect leisure-time MET in adulthood. This is useful for interpretation of the results and future implications.

In general, the reliability of physical activity questionnaires is acceptable, whereas the validity is moderate at best (Helmerhorst et al. 2012). Especially, the validity of estimations on the intensity of physical activity are varying (Dowd et al. 2018), which mostly concerns the LTPA levels in this thesis. The usage of previously estimated MET values increased the comparability of the present results, but not the validity since METs are only estimates of energy expenditure, which do not account for individuals' characteristics (Kozey et al. 2010). Thus, usage of MET values may lead to potential over- and underestimations of LTPA intensity in heterogeneous populations, yet is still a standardized method in epidemiological studies (Ainsworth et al. 2011). In terms of age, the FinnTwin16 study sample is very homogenous, as well as being capable of remembering and responding (Warren et al. 2010). The recall bias was also reduced with reporting the current LTPA level at age 17 and 34 instead of a retrospective questionnaire. The LTPA items in the FinnTwin16 study have been validated and show high correlation with interview-based data, supporting the appropriate reliability of the measures (Leskinen et al. 2009; Waller et al. 2008). Overall, the LTPA items covered all types of leisure-time and commuting-related activities, as well as enabled calculation of ltMET indices and assessment of the quantity and quality of sport activities participated in.

The assessment of spinal pains was based on a single item inquiring about the frequency of LBP and NSP (II) during the past six months and two further items on LBP ever lasting over one day (III). These do not represent the standardized definitions of LBP or NSP, including pain intensity, impact on life and seeking of medical care, which reduces especially the comparability of the results (Dionne et al. 2008; Guzman et al. 2008). An additional limitation of the definitions was the lacking description of the pain area in the FinnTwin16 questionnaires used, either in words or with visual means, that may reduce the validity of the measures. Further, evidence shows that pain reported to a wider area, e.g., neck–shoulder region versus neck, leads to higher prevalences of pain, whereas broader questionnaires including several items on pain detect lower pain prevalences (Hogg-Johnson et al. 2008). Thus, these features may have counterbalanced each other in the present studies. Another counterbalancing effect may exist among individuals with pain who tend to underestimate their physical activity levels in contrast to the usually detected overestimation of physical activity participation in self-reports (Klesges et al. 1990; Kremer et al. 1981). In the FinnTwin16 study sample, those with long-term diseases and disabilities hindering daily activities, however, reported similar LTPA levels but more frequent spinal pain. In general, self-reported musculoskeletal diseases seem to have a fair to good test–retest reliability which depends on the question wording and recall period (Picavet and Hazes 2003). An item inquiring "ever" having back pain, as in Study III, has shown relatively good test–retest reliability (Gill et al. 2016). In present studies, the short recall period "over the past six months" likely reduced the recall bias.

Due to the aim of the FinnTwin16 study to investigate several health behaviors, it was possible to adjust the analyses with multiple important covariates. However, not all covariates, such as sleeping problems, were available from every survey wave. Additionally, in longitudinal analyses the same covariate, such as smoking, could not be included from baseline and follow-up due to high intercorrelations. The longitudinal multivariate analyses in Studies I and II included primarily covariates from the adulthood questionnaire since those had higher correlations with outcome variables than similar measures from adolescence. Ideally, however, the covariates should have been assessed at baseline, similar to the exposure.

In summary, all present studies used similarly categorized variables which may have reduced statistical power in the analyses but also counterbalanced some overreportation of LTPA and sport activities, as well as increased the comparability between the studies. The FinnTwin16 study did not provide all the required information for standardized or ideal measurements of spinal pains or diversity of sport activities. However, the twin cohort study exploring multiple health behaviors provided measurements on several important confounders which enabled extensive adjustments in the analyses, including adjusting for unmeasured familial factors. Overall, future studies are recommended to include specific assessment of the frequency and intensity of sport activities participated in, objective measurement of LTPA, and standardized definitions of spinal pain.

7 CONCLUSIONS AND FUTURE IMPLICATIONS

The population-based findings presented in this thesis indicate that participation in a diversity of sport activities may be a more sustainable way to engage in LTPA than single sport participation. Sustainable means "causing little or no damage to the environment and therefore able to continue for a long time". The environment being an individual in this thesis. The specific main findings and conclusions are the following:

I. Females who participated in 5 or more sport activities in adolescence engaged in more LTPA in adulthood. Shared familial factors may confound the detected association.

II. In adulthood, those who participated in 5 or more sport activities had less weekly LBP but no less NSP, which might have been partly due to confounding by shared familial factors. Participation in several sport activities during adolescence had no association with either LBP or NSP in adulthood.

III. Over one day episodes of radiating and non-radiating LBP were less common among adult males and females who participated in several sport activities, but only before adjusting for known confounders. In cross-section, both radiating and non-radiating LBP seemed less common among males and females who participated in endurance sports, such as running and cycling.

A growing body of evidence supports that children and adolescents, even those aiming to become athletes, should be encouraged to participate in a diversity of sport activities to promote lifelong physical activity. By the definition of sport activity in this thesis, participation in sports and activities with and especially without a competitive nature should be made possible. The findings of this thesis indicate that both the quantity and quality of sport activities participated in during adolescence relate to LTPA levels in adulthood. Participation in a higher quantity of sport activities likely increases LTPA levels in every life phase, whereas participation in different qualities of sport activities raises the probability to engage in not only moderate and/or vigorous activities, but also muscle strengthening and balance/agility/flexibility-improving activities. In fact, current physical activity guidelines also encourage adults to participate in a diversity of physical activities to achieve the numerous health benefits. Thus far, the knowledge on factors (including both genetic and environmental) influencing the adherence of physical activity guidelines is scarce and should be broadened with a view to more effective implementation and promotion.

The potential health benefits, including less spinal pain, related to participation in a diversity of sport activities should also be studied further in large cohort studies. Studies II and III showed for the first time that participation in a diversity of sport activities may be related to less non-specific and radiating LBP in adulthood. Experiences in several sport activities might help to maintain LTPA despite the pain and reduce the risk of fear-avoidance beliefs winning over. However, more longitudinal evidence from different life phases is required to confirm the direction of association between participation in a diversity of sport activities and spinal pain later in life. The prevention of spinal pains burdening individuals and societies is highly warranted.

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APPENDIX

Questionnaire items of interest from the 2nd wave of the Finntwin16 study

17. How often do you exercise or do sports during your leisure time? (school physical activities do not count here)

1 not at all

2 less than once a month

3 1-2 times a month

4 about once a week

5 2-3 times a week

6 4-5 times a week

7 just about every day

18. What sorts of leisure-time physical exercises do you do? (school physical activities do not count here). Circle as many choices as apply to you.

1 I do not do any physical exercises
2 bicycling
3 jogging
4 swimming
5 cross-country skiing
6 slalom, downhill skiing
7 body building
8 aerobics
9 gymnastics
10 tennis
11 football
12 volleyball
13 badminton
14 baseball
15 basketball
16 bandy
17 ice hockey
18 ice skating
19 weight lifting
20 other, what?

Questionnaire items of interest from the 5th wave of the Finntwin16 study

12. During the past 6 months, have you had any of the following symptoms, and if so, how often?

	Seldom or Never	Approx. Once a month	Approx. Once a week	Nearly every day
Stomach aches	1	2	3	4
Tension or nervousness	1	2	3	4
Difficulty getting to sleep or waking up at Night	1	2	3	4
Headaches	1	2	3	4
Low back pain	1	2	3	4
Pain in the neck or shoulders	1	2	3	4

13. Have you ever had backache lasting for a day or longer?

1 never → skip question 15
2 1 to 2 times
3 3 to 9 times
4 10 times or more

14. What was you backache like, when it was at the worst?

1 sciatica (pain going down the leg from the lower back)
2 lumbago (sudden attack of pain in the back)
3 other back disease, specify?

32. How physically demanding is your work or studies?

1 My work or studying is mostly sedentary and I do not walk much at work

2 I walk quite a lot but I do not need to lift or carry heavy objects

3 I have to walk and lift a lot

4 My work is heavy manual work where I have to lift or carry heavy objects, dig, shovel, hammer, etc.

5 I am not working or studying at the moment

33. How often do you exercise or do sports during your leisure time?

1 Not at all

2 Less than once a month

3 One or two times a month

4 About once a week

5 Two or three times a week

6 Four or five times a week

7 Just about every day

34. How intense are you leisure-time activities usually?

1 equal to walking

2 walking + light jogging

3 light jogging

4 running

35. What is the mean duration of leisure time activity?

1 less than 30 mins

2 30-59 mins

3 1 hour – 1 hour 59 mins

4 2 hours and more

36. What is your leisure-time physical activity like?
(you may choose several items)

1 walking/ nordic walking
2 jogging
3 cycling
4 cross country skiing
5 swimming/ aqua jogging
6 rollerskating/ skating
7 working out in the gym
8 aerobics
9 gymnastics
10 dance
11 floorball
12 soccer
13 ice hockey
14 rink hockey
15 volleyball
16 basketball
17 Finnish baseball
18 badminton
19 squash
20 tennis
21 golf
22 slalom/ snowboarding
23 riding
24 orienteering
25 rowing/ canoeing
26 martial arts
27 other, please specify